

Stefan Ihde

Principles of B0I



Clinical, Scientific and
Practical Guidelines to 4-D
Dental Implantology

DVD-VIDEO



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to 4-D Dental Implantology

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to 4-D Dental Implantology

With DVD

With 388 Figures and 8 Tables

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Clinical observation of unexpected and undesirable treatment outcomes provided permanent motivation for further research into the procedure of basal osseointegration per se and of pertinent implants, tools and treatment strategies. Cordial thanks to the team at the Gommiswald Dental Clinic, whose good ideas and commitment helped me keep up my motivation throughout all these years.

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August 2004

Stefan Ihde

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Struggles and Successes

Implantology is, like chess, governed by the laws of Nature. We cannot see our opponent, but we know that she is fair, honest and patient. Adapted from Warrior of the Light: A manual by Paulo Coelho

1.1 Struggles

When too many people agree on the same subject, it is high time to call it into question. Few other areas of medicine are better characterized by this statement than dental implantology. Why? Because both academic “researchers” and practitioners focus their efforts solely on crestal implants. In other words, they completely ignore any designs or concepts other than screws and cylinders, which guide the masticatory forces, into bone areas that mainly consist of cancellous tissue. If the available vertical bone supply is insufficient, measures are taken to rebuild the morphology of the bone tissue – whether by transplantation, by augmentation or by induced growth. Unless aesthetic considerations play a major role, these modifications of the bone situation are performed solely to facilitate the use of crestal implants, which would be impossible to insert otherwise. In many cases, these adjuvant measures are considerably more time-consuming and more expensive than the patient can afford. Meanwhile, no implant treatment is performed *whatsoever*, and the patient is left without an adequate fixed restoration. At the same time, the focus of dental implant treatment tends to shift away from the dental offices as these adjuvant measures gain respectability, towards the specialists capable of performing them. Due to the additional cost of these adjuvant measures, many patients are unable to afford adequate implant treatment. The consequence is that their masticatory function cannot be restored in a truly comprehensive manner.

The implant technique of “basal osseointegration” (BOI) has been developed with a view to addressing the situations outlined above, among other problems. In this book we are going to explain why lateral access to the jaw bone should be the standard technique in dental implantology. Conventional implant designs can occasionally be used as additional treatment options.

Some dental “experts”, sharing neither the vision nor the experience of BOI users, have in the past raised vocal opposition to this system. It is not uncommon for traditionalists, who once rose to

fame by using specific methods, to eagerly oppose the obsolescence of their knowledge by obstructing progress actively. In their capacity as court-appointed experts, they can literally boycott new treatments for a long time.

Due to an almost religious belief in scientific medicine – it has been argued that this belief is a substitute for religion itself (Lütz 2002) – patients are often unable to inform themselves in a realistic manner about novel treatment modalities. Nevertheless, BOI implants have become increasingly popular in recent years. As a result of the high degree of patient satisfaction, the patients ultimately “vote with their feet”.

No doubt, treatment with BOI implants can only be performed and its outcome evaluated in a competent manner by users who have been thoroughly trained in the technique and are up to date on the current experience. Anyone rejecting the technique out of hand will of course never be able to acquire and master it. We shall therefore present the BOI technology in this book, demonstrate its practicability, and document its successful outcome based on specific case reports.

Dentists who perform BOI treatments are still required to have additional solid training. What we are currently observing is that more and more universities are becoming active in this field, having first acquired the technique themselves. Since the universities’ *raison d’être* is the propagation of knowledge, this development of course deserves praise. By contrast with most current teachings in the realm of crestal implantology, the propagation of knowledge about the real-life properties of bone and its behaviour play a prominent role in BOI. Of equally great importance are prosthodontic concepts and the teaching of how to restore the human masticatory function. Many universities were too late getting on the BOI train. One might well ask how this could have happened – several factors come to mind:

- A comprehensive concept of mastication is absent from the academic teaching curriculum. Some universities do not currently teach this field at all, while others teach quite divergent views.
- The teaching and practice of dental implantology is spread across several departments: prosthodontic

departments implant “simpler” cases, departments of oral surgery implant “more difficult” cases, and the maxillofacial surgeons are holding their own when it comes to maintaining their niche in maximally invasive bone transplantations. Even orthodontists occupy a small region within dental implantology related to enossal anchorage. Needless to say, all these departments fight each other for access to the few patients and to third-party research grants.

- In a way, BOI implantology is a part of all of these subfields, an interdisciplinary endeavour, focussing on functional therapy and with a strong surgical aspect. Psycho-social and economical aspects also play a role: Not only is the BOI procedure the fastest and safest treatment procedure in dental implantology today, it is also the cheapest.
- Some universities increasingly realize that post-graduate instruction in BOI implantology is an immense field that might very well generate huge amounts of financial resources. Students from all the sub-disciplines cited above need some training in BOI implantology – and ultimately all active or future dentists.

During my BOI-related travelling activities, I have found that fellow dentists in the ex-Communist countries are much more familiar with the basics of bone physiology and mastication therapy than dentists in the former Western countries. However, interdisciplinary training seems to be scarce at some institutions.

According to Scortecchi (2001), 99% of patients not eligible for treatment with screw implants can be treated by BOI without bone transplantation. This high success rate is in accordance with our own experience.

At present, insurance companies are beginning to find out that BOI treatment is by far more safe, faster and cheaper than conventional bone augmentation followed by crestal implantation. On the other hand, the appearance of BOI on the stage means that more patients will undergo treatment more readily: a great number of patients who have toyed with the idea of implant treatment before but shied away from bone transplantation or prolonged chair times are beginning to see a realistic chance of obtaining fixed restorations on implants within an acceptable timeframe.

It is necessary and fair to mention that disk implantology and the BOI technique, like all dental implant techniques, went through an early phase of treatment failures with implants and prosthetic superstructures being lost. The same learning curve had to be mastered in the development of all other implant techniques or, for that matter, any other medical treatment. Many problems in connection

with basal osseointegration arose from the fact that a number of views on procedures, beliefs and treatment approaches were adopted from untested crestal implantology. They were adopted without knowing the reasons why the original technique had actually worked, or not worked, in specific cases. In our view, some of the “rules” that evolved from the literature on crestal implantology are definitely wrong. Some of them cannot be generalized but are based solely on empirical observations that may possibly apply to crestal implants. Anyway most of them had to be revised in the past decade.

1.2 Other Major Considerations

Learning the surgical procedure is not difficult *per se* if good instruction is provided. Trainees have to need to shake off several prejudices that are considered widely to be facts.

1. A common misconception today is that the lateral osteotomy for BOI cannot be created with the same low-speed instruments as commonly used in crestal implantology. Regardless, however, there are great advantages in using high-speed instruments and ultrasonic tools not only on teeth, but also in the bone.
2. The claim that the temperatures associated with high-speed instruments will affect bone healing is defeated by clinical experience.
3. The concept of immediate loading with BOI implants is continually discussed under false premises, as most concepts of crestal implantology rely on unloaded osseointegration of implants. Crestal implants, especially in the maxilla, are inserted in bone areas that consist mainly of cancellous tissue. These areas are not capable of accepting and transmitting masticatory loads in the early phases of treatment. This only becomes possible once the bone tissue has been adequately conditioned by the endosseous implant surface. Chapters 9 and 23 will provide the reader with the necessary background to weigh up the pros and cons of immediate loading more realistically.
4. The claim that implant placement is contraindicated in periodontally involved areas is also based on false premises. In crestal implantology sterile insertion is a major requirement since no gap is left for suppuration. Pre-existing residual osteitis within the bone or micro-organisms introduced during the insertion can bring treatment with crestal implants to an end very quickly. BOI implants, by contrast, are highly resistant to infection. The reader is referred to Chapters 8 and 23 for a detailed discussion of this issue.

1.3 Anatomical Landmarks as Moving Targets

The BOI technique requires not only a three-dimensional concept of the structures of the human skull, but also a notion of the morphological changes that the skull will undergo both with age and as a result of the planned treatment. The experience with BOI implants has yielded empirical guidelines that predict where an implant should be placed, how it should be put into function by prosthetic means and what types of treatment will ensure a successful outcome.

Even though a sustainable implant site may be unusable at the time of first implantation, the treatment can still be planned in such a way that the required bone volume will be building up under a long-term temporary restoration. Tricky concepts like these are a challenge in our everyday practice, but ultimately they are logical. The successive treatment steps are easy to perform in the hands of well-versed practitioners.

Additional difficulties arise in situations with a mineralization pattern not consistent with what would “normally” be expected, or with an adequate bone volume not being present at strategically favourable implant positions. This may occur at the beginning of or during a treatment. Ultimately, the goal of treatment is to create stable conditions even though the functional potential at the beginning of treatment may be such that stability cannot be attained immediately.

1.4 Winds of Change

At a time when cars are built to last, with fully galvanized or all-aluminium chassis for corrosion protection – it is difficult to explain to some patients that definitive prosthetic restorations, once they have been inserted in the mouth, need to be adjusted periodically to ensure their longevity in a visco-elastic intra-oral environment that is subject to continuous mechanical and static changes. Also, the fact that implant treatments are relatively expensive leads patients to believe that they can expect a stable definitive product in return for their money with no need for subsequent maintenance therapies. Patients would like to think that their own collaboration is no longer a major factor in the outcome of the bone-implant-restoration complex once the installation phase has been completed. They tend to overlook that cars, too, need regular maintenance and checking and are periodically fitted with new

tyres to resist a mechanically hostile environment. In cars, the maintenance costs are a substantial portion of the acquisition cost.

Implant-borne restorations need maintenance and so do the implants themselves. The frequency of these visits will depend on how unusual the case was at the time of presentation and how fast the masticatory system can be guided back to regular function.

Sustainable implantological results can only be obtained if the implants incorporated into the functional complex of the skull do not affect the functional morphological changes of the jawbone. Preferably, they should be placed in areas where the bone is safe from resorption, so that enough volume will be available for many years to come. These safe regions include not only the mandibular anterior segment but other areas as well. Crestal implants, however, cannot be placed in these areas (e.g. because of the mandibular nerve) or, at best, require awkward adjuvant procedures to be inserted. In these cases, BOI implants are a simple alternative to realize a fixed restoration after all. Lost bone structures will rebuild by themselves wherever functional loads induce them to rebuild or, for that matter, wherever the dentist ingeniously directs these functional loads. Therefore, the long-term success of treatment in terms of bone gain will depend much more on the prosthetic restoration than on the surgical procedure of implant insertion. Implant sites that are basically stable may “suddenly” lose their stability if the functional pattern of the masticatory system changes adversely. These interactions are not self-explanatory. The reader is referred to Chapters 9 and 10 for a detailed discussion.

Extensive bone augmentation procedures, although really unnecessary, are still being performed. The persistent use and propagation of those techniques has in effect become a hallmark of dental implantology. Almost all patients would be eligible for fixed restorations if only the implants were selected to match the bone. The effectiveness of BOI as a treatment option has been well established for a long time. Here, “effectiveness” means the ability to restore a balanced masticatory function. The question whether this objective can be achieved and maintained constitutes the only basis for verifying the desired “effect”. The goal must be to minimize the number of surgical procedures and to ensure a good masticatory function based on fixed restorations at all times, even during difficult treatment phases.

A solid understanding of the BOI technique requires a firm grounding in biomechanics, bone function and mastication. With this in mind, the reader may want to read Chapters 9, 10 and 23 first.

1.5 The Rocky Road to Success

Today, implantological treatment goals can be achieved more reliably, more easily and less expensively than ever. Well-versed practitioners have the option of using BOI implants, which are the state-of-the-art descendants of the first-generation T₃Ds,¹ the second-generation disk implants. With BOI implants, fixed restorations can be placed even in severely compromised alveolar ridges. Furthermore, they can be immediately loaded in the majority of cases. Since BOI implants utilize the horizontal dimension of the ridge (which is always intact), the vertical bone requirement is very small.

In the late 1980s, disk implantology was still dismissed as an uncommon technique used only by outsiders. Further developments, however, have given rise to the BOI technique, which today is the most frequently used restorative method to treat advanced ridge resorption in a single procedure, not least because it is the only technique allowing a genuinely one-step surgical approach. The technique has reached an extraordinary degree of maturity because it has been developed, over decades, outside Academia by practitioners only. Also, the fact that manufacturers have embraced the input from clinical users directly and without delay has greatly accelerated the development of the materials as well as of the method.

Meanwhile, the progress made in crestal implantology has been incorporated to the benefit of BOI as well, the developments in surface technology being one example.

Another aspect to keep in mind is that the manufacture of BOI implants became affordable only recently by advanced CNC-controlled technology. This technology and the sophisticated manufacturing techniques associated with it have created the possibility to design stable and delicately shaped implants from titanium ingots with known basic properties without significantly altering the structure of the material (Figs. 1.1–1.7). We are indebted to the engineers who were skilful enough to translate our requests concerning implant design into finished products.

Crestal implantology no doubt offers optimal ways of restorative treatment in situations where the implants can be inserted without delay and with no need for adjuvant procedures. Unfortunately, a great many patients do not meet these criteria. This is particularly true of the posterior segments of the



Fig. 1.1. Advanced CNC milling machines are capable of shaping many different BOI designs with defined properties from a single bar of massive titanium



Fig. 1.2. View of the manufacturing chamber of a CNC milling machine

maxilla and mandible. Whenever oral conditions are less than ideal for crestal implants, the advantages of the BOI approach are obvious:

- Low degree of invasiveness (no augmentation, distraction or transplantation)
- One-step procedure
- Simple repair in case of problems
- Combination with natural teeth possible
- Combination with crestal implants possible
- Manageable system (few components)
- Simple laboratory technique
- Extremely high success rates

¹ The first tridimensional implants were designated “T₃D” by Jean-Marc Julliet.

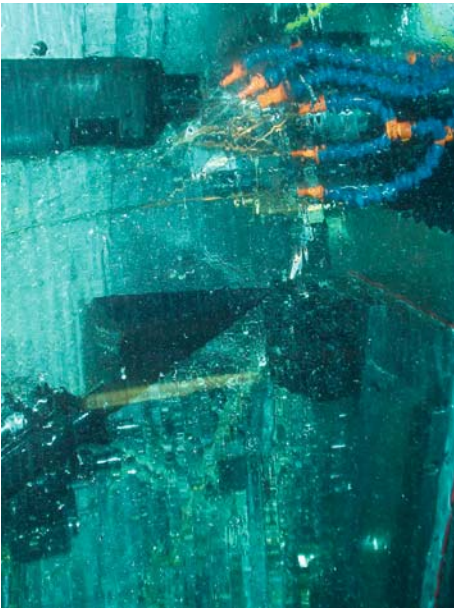


Fig. 1.3. It is impossible to watch the milling steps due to the extensive cooling requirements

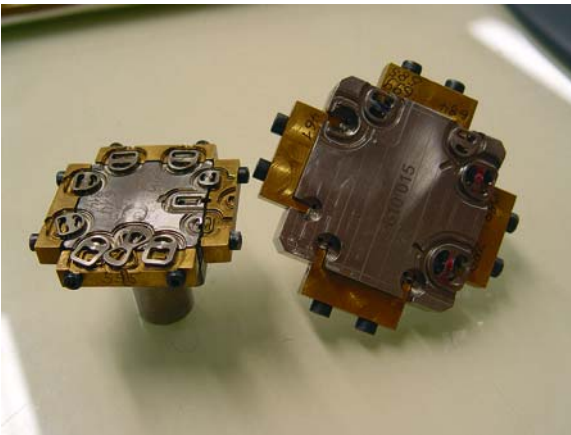


Fig. 1.4. Some BOI designs need to be adjusted in a second and third step by abrasive instruments. For this purpose, they are mounted on individual tray compartments

Disadvantages of the BOI system include:

- The stock-keeping requirements are greater than in crestal implantology, i.e. it will always be necessary to keep a few more implants handy to avoid extensive planning including three-dimensional exploration of bone conditions.
- The technique poses substantial challenges, for instructors and users alike, as far as the surgical and prosthetic treatment stages and the substantial knowledge requirements in the fields of biomechanics and bone physiology are concerned.



Fig. 1.5. The same triple-disk BOI design in different stages of processing

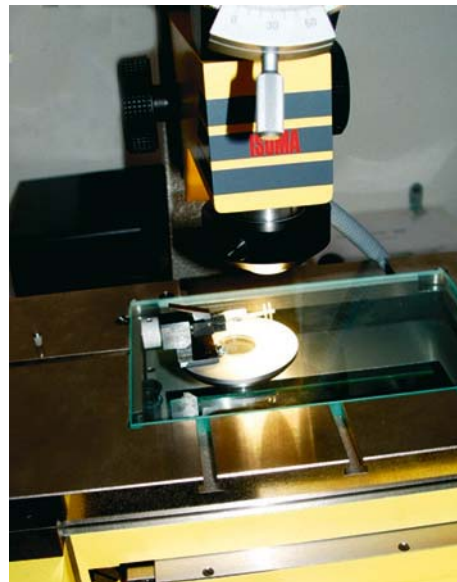


Fig. 1.6. Although CNC milling machines are extremely accurate and precise, each specimen is thoroughly inspected

From a business perspective, however, these disadvantages turn out to be advantages after all, since mastering the learning curve will give dentists a comfortable edge over any competitors in the field of implantology.

The question why the outcome of BOI implants is so much better than the results with crestal implants – which specifically includes the survival rates as well – remains to be conclusively answered. Presumably, the prognosis of BOI implants is better from the start, as the blood supply to the bone remains largely intact as a result of the “skeletalized” enossal implant fixture. Surface-enhanced crestal implants are susceptible to peri-implantitis, which



Fig. 1.7. An extremely motivated and well-trained team of CNC specialists guarantees reliable quality in the production of BOI implants. During the production phase, any effort must be made is to leave the structure and the strength of the titanium and its elastic properties unaltered

may lead to progressive ridge resorption. With the BOI technique, this is less of a problem due to the narrow polished emergence of the implants. In addition, the site of bacterial invasion is far away from the site of force transmission. Hence the bone is not burdened with two tasks at the same time. Crater-style collapses are usually avoided this way. Moreover, the implant areas where load transmission takes place are integrated in such a way that the osteogenetic and osteoprotective properties of the cortical bone are optimally utilized.

In BOI systems, the fate of the alveolar ridge is not linked to the fate of the implant-restoration complex, since the areas where load transmission takes place are spatially separated from the masticatory surfaces. This fact is obvious from the very design of BOI implants. For successful insertion and load transmission, it is irrelevant whether the vertical portion of the implant is embedded in air or in fluid. It is also irrelevant whether bone tissue is deposited directly on the implant surface in this area. This has many desirable implications:

- Aesthetic considerations aside, the success of implant therapy does not depend on the presence of alveolar bone.
- In the presence of dysgnathia, masticatory surfaces can be installed at sites that are spatially independent of the skeletal base.

A good emergence profile of restorations on external BOI systems is achieved by workaround solutions due to the small diameter of the threaded pin. For this reason, BOI implant restorations in the aesthetic zone are somewhat harder to realize than with crestal implants (provided there is enough vertical bone to place them) and require a good measure

of anticipation on the dentist's part for correct positioning of the abutments.

Treatment success depends to approximately 80% on prosthetic concepts and their execution and maintenance and only to 20% on the surgical procedure. And it depends on reliable, good compliance of the patients. The patient must be informed about this and must know that immediate load does not mean the immediate end of active treatment phase.

1.6 Scope of This Book

This volume describes the application techniques, surgical approaches, prosthetic methods and maintenance therapies in connection with BOI implants. Some types of force transmission areas are examined by FEM analysis of elastic behaviour under physiologic loading. Healing patterns with or without loading will be compared to those of screw implants based on animal experiments. Both the FEM results and the impressive histological data presented in this book will make it easier for the reader to develop a basic understanding of BOI technology and the bone reaction involved.

Other chapters deal with specific anatomical situations and how they are addressed with BOI implants. Emphasis has been placed on Angle class III and II skeletal relationships, on resorbed mandibular ridges, on cantilever situations, and on treatment options in the posterior segment of the maxilla. Treatment concepts relying on multiple implants are compared to strategic implant placement.

An entire chapter is devoted to the theoretical basis of immediate loading. This will include a critical review of the literature referred to by crestal implantologists.

The BOI technique is compared to conventional treatment concepts using bone augmentation, bone grafts or osseodistraction. Critical analysis reveals that the conventional multi-step procedures used to augment the maxillary sinus or the distal mandible are no longer acceptable in the era of basal osseointegration. Indeed, they belong to the cruellest chapters in the history of medicine and should be abandoned as quickly as possible. This is particularly true of iliac bone grafts for sinus floor augmentation. Against this background, the legal implications of the discussed treatment concepts are compared based on current legislation in Germany, the European Union and the United States.

Repetitio est mater studiorum. Facts that are relevant in different connections are repeatedly explained in this book with shifting emphasis depending on the context. This allows the reader to start reading wherever he or she pleases, and it ensures and elucidates the continuity of related chapters.

1.7 Evidence and Trust

Medical writing must be based on evidence. This is an indispensable requirement because evidence is the only way of obtaining certainty. These certainties obtained by way of evidence are more likely to stand the test of time – at least parts thereof – and provided that the questions and perspectives from which they were derived stand the test of time as well. Of course, this presupposes that the authors were honest in the first place.

“BOI technology is not based on scientific evidence.” Statements of this kind can be heard time and again from people trying to avoid the trouble of learning the technique and of screening the literature for pertinent reports, which are abundantly present, and to read them. Referring such critics to the piles of existing literature on the subject will usually silence them. Much literature has been extensively studied and evaluated for this book. Given the unwieldy mass of dental and medical literature that has accumulated over the centuries, no claim to completeness is made. What is striking in retrospect is the fact that a substantial basis of knowledge that is no longer a part of current dental training was already disclosed by early authors who have more or less fallen into oblivion. The same knowledge reappears in a great number of “modern” publications, the only difference really being in the words used. In retrospect, these

early authors – including Wolff, Thielmann, Gerber, Gysi, Frost, Martin and Burr or Planas – laid out the entire armamentarium for BOI a long time ago. However, their various findings and explanations as to the practical implementation of these systems have never been formally consolidated. The present book was written to fill this gap and to encourage the reading of historical articles and books.

This book reflects practical experience and examines it against known concepts in prosthodontics, surgery, and physiology – especially in bone mechanics. The result will be that all treatment methods described here have a sound scientific foundation derived from a variety of dental sub-specialties.

Some of the chapters include bar diagrams with statistical results and overviews without detailing the data pool from which they were derived. These diagrams, unless otherwise stated, are by default based on the total number of consecutive implants inserted at our hospital. The total number of implants detailed in these diagrams will always be based on the latest update of our database and may thus vary depending on the creation date of a given passage. It goes without saying that calculations based on larger samples or longer observation periods will involve a higher level of significance.

Knowledge changes rapidly and has always been in a state of flux. This is not a recent development. The responsibility to keep abreast of developments in dental implantology lies with the reader. As Abraham Lincoln put it so aptly: “A politician can fool most people on almost every issue most of the time, but nobody can fool everybody on every single issue all of the time”. This is as true of authors as it is of politicians – and for the reader to consider.

1.8 The Internet

The Internet has paved the way for the breakthrough of BOI technology and will continue to be a major catalyst. There are two reasons for this. For one thing, the Internet has created an opportunity for practitioners to exchange their experiences by transmitting pictures and radiographs, enabling them to join forces in a coordinated manner to work out optimal treatments for difficult cases. Today it is possible to exchange video documentation of surgical procedures, and writings can be disseminated at the touch of a button. It has been said that thoughts, once they have been published on the World Wide Web, can never be extinguished.

For another thing, the Internet has been the first medium through which patients could learn about the mere existence of BOI implants as a

treatment option, so that certain obstructionists in our profession are no longer able to suppress the technique successfully. Patients will ultimately “vote with their feet” – i.e. they will walk away from treatment options that are both invasive and expensive (Isfort et al. 2002).

1.9

Results and Outcomes (Apples and Oranges)

In the literature on crestal implantology, it is common practice to calculate success rates for implants from their probability of survival. The current statistical approach is to sweep all implants that were lost before being loaded by a prosthetic structure under the carpet. These losses are dismissed as “unfortunate”, “infection-related”, “idiopathic” or simply as “unexplainable”. They never enter the statistics. Neither do the statistics account for implants that could not be installed in the first place, because the adjuvant procedure of bone augmentation or osseodistraction had failed, or for those cases in which an attempt at therapy had not been made because of various “contraindications” connected with crestal implants. In addition those cases have to enter the equation, which have not been treated at all, because the adjuvant procedures were not compatible with the lifestyle of the patients (i. e. housewives who did not want to present themselves to their husbands without teeth during the healing period of the augmentation; or businessmen who stayed with their dentures because they could not afford to stay away from their job for so many appointments).

Also, we have to consider, that quite a few potential patients would be willing to pay for bone augmentations (or BOI!) to get fixed teeth, but they do not want to undergo lengthy suffering.

1.10

The Vision

While it is clear that the idealistic notion of all patients having a lifelong right to fixed teeth will never come true, it is also clear that this goal could not possibly be achieved by crestal implantology alone. The various reasons for this have been mentioned previously in this chapter, and they are going to be demonstrated and explained in greater detail throughout this book. It is not only the high costs specifically arising in connection with the invasive adjuvant procedures needed for crestal implant treatment that will often prevent any more extensive implant-based restorations from being realized, but it is also that many patients cannot be

treated by crestal implantology altogether, for well-known pathophysiological reasons. This is not to say that crestal implants are inferior, let alone unsuited, in principle. Rather, the highly invasive nature and costliness of the necessary adjuvant procedures are prohibitive to their widespread use. Therefore, crestal implants are clearly not a candidate in the quest for offering dental implants on a broad scale. BOI implants are perfectly able and ready to fill this gap. The present book has been written to support the popularization of this technique.

1.11

Listening to Patients’ Demands

Patients have the following expectations of implant treatment:

- They want any missing teeth to be replaced at minimum invasiveness in a single procedure; and they want to be through with this problem once and for all.
- They want the entire treatment to be affordable.
- They want all parts of the restoration to be well accessible for brushing and flossing; after all, many of them lost their teeth due to poor oral hygiene. Any bad habits such as smoking and careless brushing/flossing should be abandoned.
- They mainly want to have “fixed teeth” restored; they are not interested in having their bone volume increased and rarely attach great importance to a natural “emergence profile” (a concept overused in the literature), but they simply wish to have their problem solved in a down-to-earth and aesthetically acceptable manner.

In real life, these expectations are rarely met by crestal implant systems (screw implants), due to the following reasons:

- Healing periods are usually long.
- In many cases, several procedures become necessary.
- If bone volume is insufficient, adjuvant procedures become necessary that are usually more invasive and more expensive than the implant procedure itself.
- In addition to being very expensive, these adjuvant procedures carry high a risk of infection or necrosis.
- Despite the large scope of therapy, a considerable number of patients cannot be treated with crestal implants at all.
- Patients treated with screw implants will face intensive oral hygiene requirements.
- Smokers have an increased risk of implant loss.

BOI implants are also a desirable option from the dentist's perspective. The system can be established in the dental office at low cost, requires a manageable degree of additional training, involves a small number of prosthetic components, and offers a high success rate. *BOI implants are a uniquely optimized therapeutic option.* In many situations, BOI systems can be used in conjunction with crestal implants to optimally take advantage of both systems.

Treatment with BOI implants is simpler and quicker than crestal implant therapy since no augmentation procedures are involved. Based on our experience with more than 1,000 patient cases treated with BOI implants, 95% of patients can be successfully treated with fixed restorations in an immediate and definitive manner. In the remaining

5%, a successful outcome can usually be ensured by replacing any failed implants in a secondary procedure. Situations in which a successful outcome cannot be achieved are very rare (about 0.5% of patients). These cases must be carefully analysed and may be treatable after all by using more invasive techniques such as bone grafting as a last resort.

After thorough study of this book, you, the reader, may end up asking yourself, "Why in the world didn't we start doing things like this a long time ago?" If that happens, you will be on the right course. You will successfully circumnavigate the dense fog and steep cliffs often found on the route to dental implantology, and you will not allow yourself to be sidetracked by intentionally misleading beacons. Good luck – and have a pleasant journey!

History as Documented by Patents and Patent Applications

Science is the art of creating knowledge

It has been a long tradition in medicine that new ideas and treatment concepts are hardly ever invented inside the universities. Usually, practitioners – because they really face the patients' problems day-to-day – are the ones to develop new solutions. Not until later are the techniques adopted by universities, and usually it will be necessary, of course, to pay the universities to change their way of thinking, working and teaching. The history of BOI implantology reflects this situation, as can be seen looking at the patent situation in this field. Patents applied for and, of course, patents granted are relatively objective criteria to go by. They help us judge who the people were that have genuinely set scientific milestones and broken with traditional thinking in a constructive way.

By all accounts, the first enossal implant design that relied on a lateral insertion path and capitalized on the stability of the inner and outer cortical bone was devised in Italy (F.P. Spahn, personal communication). The disk and threaded pin were inserted separately in this design, the latter through an extra vertical drill hole. Finally both components were connected with a screw. The technological means for the manufacture of single-unit titanium implants of adequate size were not available at the time.

The first single-unit implant was developed and used by Jean-Marc Julliet (1972). This design was only available in one size and offered no basal plate resilience. In fact, this kind of resilience would have been undesirable, considering that the pin was threaded all the way to the basal plate. The scope of indications for this design was limited to areas where the basal plate reached both cortical structures, so that its use was essentially confined to the anterior segments of either jaw. Incidentally, the threaded pin was only available in one standard length and had to be reduced by the user as needed. It is interesting to read Julliet's description in the patent specification. Julliet clearly recognizes the disadvantages of implant placement without cortical support: Julliet explains that, contrary to Linkow's approach specified in U.S. patent 3,465,441, the gingival resistance and the tight pressure fit of the blade implant will soon give way to masticatory pressure. In this way, the blade is pressed

deeper into the bone and will eventually lodge right on the cortical structure. Obviously, Julliet had been closely observing the consequences to be faced when enossal implants lacking cortical support are mobilized by the prosthetic superstructure. He stated that his invention was aimed at creating a reliable type of anchorage that was simple in design and easy to insert. Julliet, however, did not really realize the importance of bicortical anchorage and the possibility of the isoelastic incorporation of a jaw-implant-restoration system.

To summarize, while the original implant design by Lobello was based on inserting two separate components, the design by Julliet featured a welded joint between the threaded pin and the basal plate. His lateral implant was granted a U.S. patent (Julliet 1975). Presumably, the only thing that Julliet had in mind was to use his own idea as inexpensively as possible. He wanted to avoid a situation in which someone else applied for a patent on the basis of his thoughts and ideas, later preventing him from using his own implants.

Some years later the French dentist Dr. Clunet-Coste (1975) applied for a patent on the manufacturing technique of a T-shaped single-unit implant, which showed some of the same essential characteristics as the design described by Julliet in 1972. The French patent was granted and remained effective until its expiry in 1996.

The rights of patent were acquired by the Eugen Kühlmann company through its subsidiary Zerca that continued to market this implant design for many years. This is also where Julliet obtained his implants.

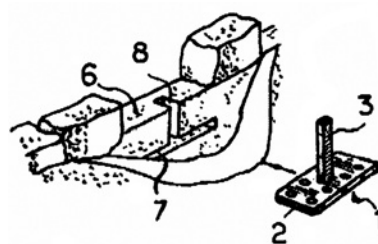


Fig. 2.1 Drawing from USP 3,925,892

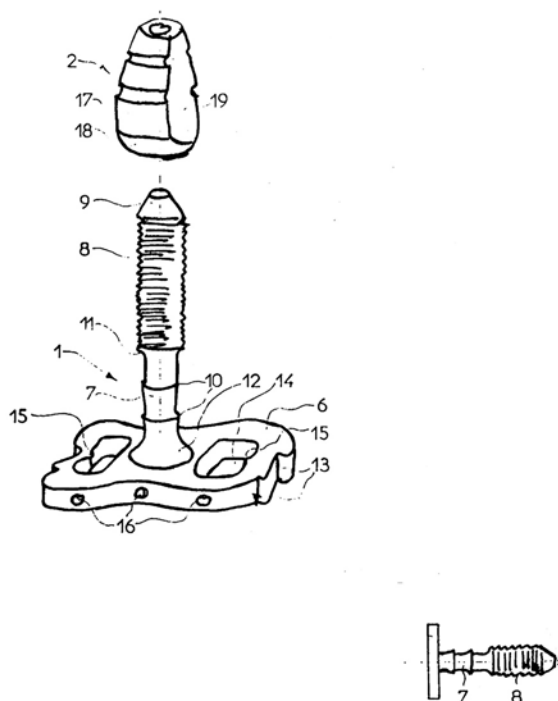


Fig. 2.2 Implant design by Dr. Clunet-Coste, France

Clunet-Coste, by the way, would initially buy his own implants in Italy to avoid paying his own licence fees. Scortecchi, in turn, acquired his Swiss-made implants via Monaco. Zerca discontinued this production line a year after Juliet's death in September 1983. Around the same time, Scortecchi entered the market with his cutters and rotationally symmetrical designs named "Diskimplant®". It appears that these developments held great appeal for Clunet-Coste himself because he allowed Scortecchi to continue producing and marketing his products without a licence (F.P. Spahn, personal communication, 2001). Anyway, taking out patents on manufacturing processes only in specific European countries is no longer meaningful these days. As a matter of fact, patents on manufacturing techniques are likely to become pointless even if confined to Europe in this era of increasingly global markets and cheap manufacturing sites in the countries of the former East Block.

Three further patents taken out by Scortecchi in the USA (1987, 1988) and in Europe (1985) added another chapter to the history of disk implantology.

In his U.S. patent, Scortecchi described an implant that served as its own insertion tool. The patent also covers some aspects of the lateral insertion process.

The idea was to design an implant surface that included cutter flutes and to remove the turbine after the bone concavity had been cut, thereby leaving the implant well anchored inside the bone. The turbines available then and today have a chuck diameter

U.S. Patent Feb. 2, 1988

Sheet 1 of 3

4,722,687

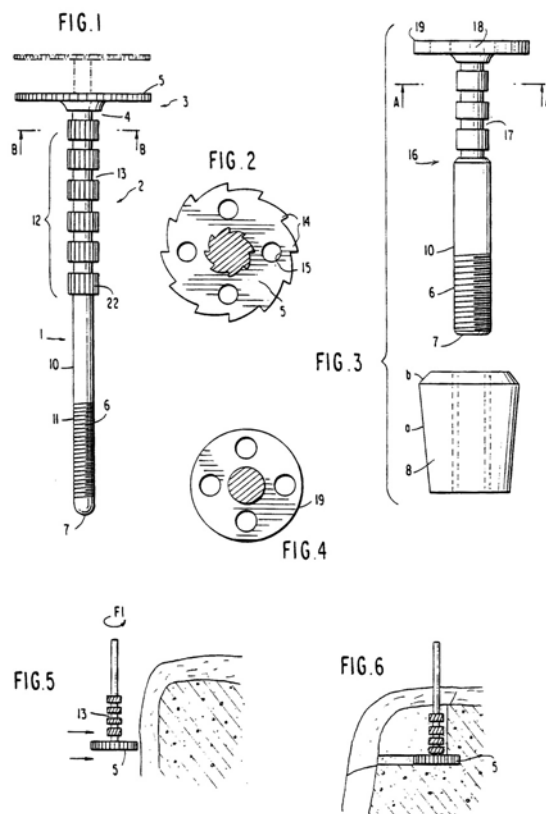


Fig. 2.3 Drawing from USP 4,722,687

of 1.6 mm, which was a limiting factor for the diameter of the implant shaft (i.e. the threaded pin). Consequently, this design routinely led to implant fractures. The system as described in the patent has never been widely marketed.

Figure 2.4 illustrates the lateral insertion path; Scortecchi envisioned a system in which the size and shape of the implant bed did not necessarily coincide with the implant design.

Item 8 in Fig. 2.5 shows that the osteotomy path was longer than the implant. This approach presupposes that the cortical bone structure in the mandible is adequately wide. It is necessary to remember that functional alterations associated with the restorative treatment or hormonal changes may lead to massive endosteal resorption. If so, the chances are that the implant will recede in lingual or vestibular direction into the newly evolving cancellous bone areas. This problem has been eliminated in the asymmetrical implant designs, which are discussed below.

The U.S. patents were granted without problems at the time. The procedure went not so smoothly

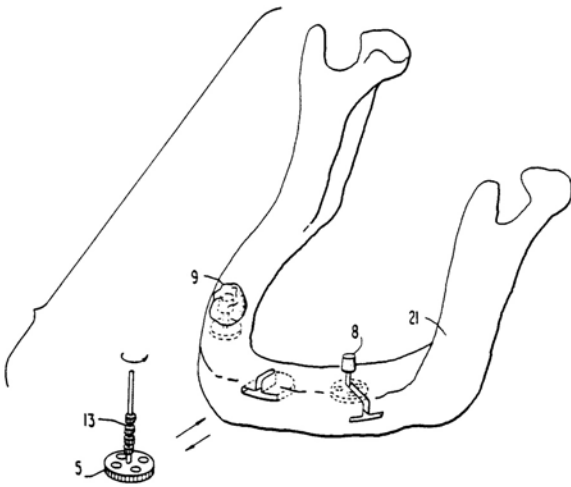


Fig. 2.4 Drawing from USP 4,722,687 and USP 4,815,974

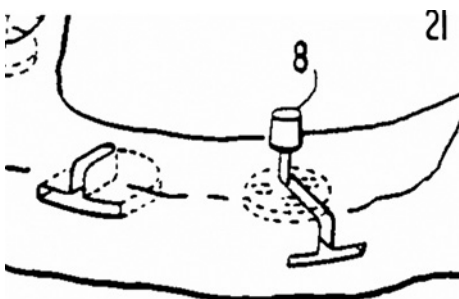


Fig. 2.5 Enlarged section of Fig. 2.4

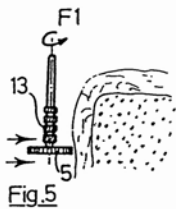


Fig. 5

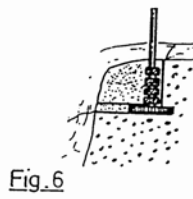


Fig. 6

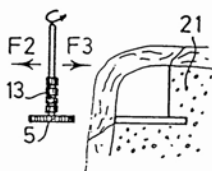


Fig. 7

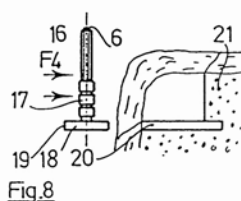


Fig. 8

Fig. 2.6 Another drawing from those productive years shows that Scortecchi envisioned the use of small rings along the shaft serving as force-transmitting surfaces and depth indicators. The implant itself also featured rings of this type. The advantage of this configuration was that it gave the surgeon a very accurate idea how long the implant needed to be. On the downside, it involved an additional risk of mucosal and bone irritation in the presence of elastic implant-restoration systems

in Europe, where the patent specification had to be revised. Meanwhile, Scortecchi had been collecting experience by using his implant designs in practice, so there was time to amend the original patent claims to reflect this experience by the time the European patent was eventually granted. The U.S. patents, by contrast, were granted almost unmodified.

Despite these developments, the resources that were funnelled into the universities for the teaching of dental implantology were invariably distributed in favour of screw implants. Industry was expecting a faster turnaround in revenues from screw implants and reasoned that the insertion techniques could be explained more readily to dentists than the procedure for blade and disk implants. Also, the risks to the prosthetic work seemed smaller if only those screw implants that were found to be intact after a healing period of 3–6 months could be fitted with a tailor-made superstructure.

In other words, the concept of immediate loading associated with the BOI system entailed the requirement that all inserted implants had to be clinically successful. Since any implant failure automatically leads to loss of the superstructure, there is always a risk of financial consequences

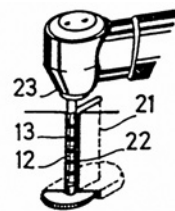


Fig. 11



Fig. 12

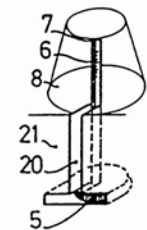


Fig. 13

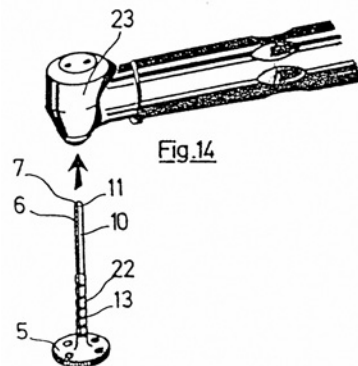


Fig. 14

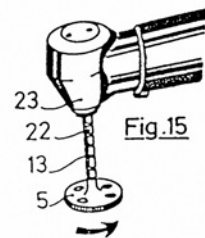


Fig. 15

Fig. 2.7 Drawings from EP o 241 962 B1. These sketches illustrate in detail the insertion procedure generating the implant bed. The vertical and horizontal dimension of the insertion path were obtained simultaneously by using a specially designed cutter

to the dentist. While BOI went through a phase of inexcusable neglect for these reasons, a flurry of adjuvant procedures for bone augmentation/grafting emerged on the scene. This development may have been a blessing for some – particularly for maxillofacial surgeons – but it has improved neither the actual success nor the theoretical potential of implant treatment.

An essential feature of this design was that implants and tools were separated. Scortecchi's patent lawyers deserve considerable respect for the fact that they succeeded, by resourceful phrasing, in incorporating as subclaim 6 the exact opposite of the original idea of the patent application, such that it escaped the reviewers' notice and formed part of the patent granted.

In 1991, Scortecchi published a retrospective study on the clinical outcomes of his Diskimplant system (Scortecchi et al. 2001). In the years 1979–1989, a total of 5,848 implants had been inserted, 590 of which had to be removed. Most of these implant losses occurred in the period 1980–1984, presumably either because the disk diameters were too small or because the threaded pins were too short. Another factor was that the original disks were not perforated at all; the next generation featured perforations that were still very small. Fractures resulting from the small diameter of the threaded pins (a consequence of adhering to the U.S. patent specification and the 1.6 mm shaft diameter) also contributed to some failures. Notwithstanding, a cumulative success rate of almost 90% over a 10-year period was a remarkable feat, considering that similar figures were also reported for screw and blade implants at the time. With Scortecchi's development of standardized cutters for implant beds, lateral implantology ultimately became an option even in the hands of less skilful surgeons. Therefore Scortecchi is rightly to be regarded as one of the “founding fathers” of lateral implantology.

In his comprehensive book on dental implantology, published in 2001, Scortecchi laid out a large number of treatment options with disk implants. He combined disk implants with “structure” screw implants, mainly for screwed bridges. His multiple implant concept based on 8–14 implants in each arch was associated with huge material requirements and enormous costs. In addition, it turned out that the bone structures would stiffen as a result of this approach. By the same token, today's implants do not feature surface enlargement to avoid irritation of the surrounding bone. As a consequence, individual implants that are embedded in elastic bone segments may turn out to be mobile when bridges are removed. This type of mobility does not have any clinical or radiographic implications. Considering the implant/restoration system as a whole, these mobile implants still constitute a stable basis for the restoration.

Other fellow dentists have also contributed ideas to the development that eventually led to basal osseointegration. The Belgian dentist Robert Streel (1980), for instance, was the first to describe bendable lateral implants. Streel postulated that implant treatment must try to achieve a perfect balance of forces. This demand is not plausible from today's perspective; after all, the bone structure in which the force-transmitting areas are embedded are not uniformly protected against resorption, either.

Areas 5 and 8 in Fig. 2.8 are the bendable lateral stubs.

The fact that disks at the implant base can be used in a completely different manner had been demonstrated by Christensen as early as in 1965. The caudal insertion path of this design has remained somewhat of an obstacle. Dentists are not accustomed to this type of surgical approach.

For the same reason, the transmandibular implant (TMI) design, although offering extremely good results in the treatment of mandibular resorption, has never been too popular among dentists. A

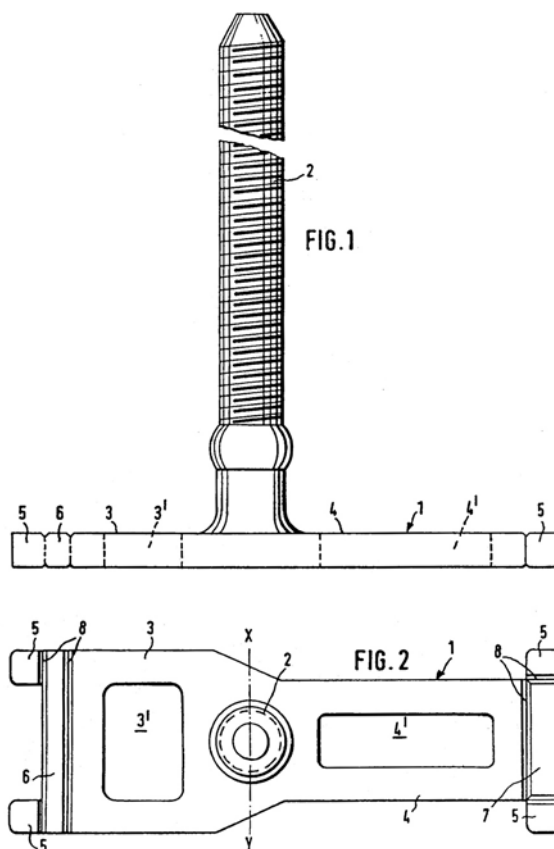


Fig. 2.8 “Perfectly balanced” disk implant with bendable lateral stubs that are intended to ensure primary stability to lateral forces. In other words, part of the design will be locked up in a subperiosteal position. This concept of basal osseointegration has survived to this day

handful of fellow dentists well versed in surgical techniques have used these implant very successfully for decades. Numerous patients have thankfully recovered their masticatory function in this way.

The TMI system has a lot in common with today's BOI system:

- The implants have no load transmission either near areas where the implant penetrates the mucosa or in the vertical implant portion.
- All load transmission takes place in areas that are safe from infection.
- Load transmission is multicortical.

Another innovative mind influencing the development of dental implants was Albert Kurtis. The design he specified in his patent of 1988 was aimed at anchoring the threaded pin deep inside the bone to endow the implant shaft with resilience and room for flexural manoeuvre while preventing infections from advancing to the load-transmitting implant segments. At that time, features such as round struts

for load deflection and round framework transitions to avoid load peaks were remarkable achievements in structural design. The blood supply in the insertion area would probably remain largely intact with this design.

Another name to be mentioned in this context is Alfred Edelmann, whose U.S. patent specification (1978) also included (albeit as a minor point) basal solutions for his implant design.

Kawahara (1989) studied the use of discontinuous surfaces and provided relevant specifications for all types of implants.

In the early 1980s – i.e. in the early phase of “disk implantology” – Scortecchi did not pay enough

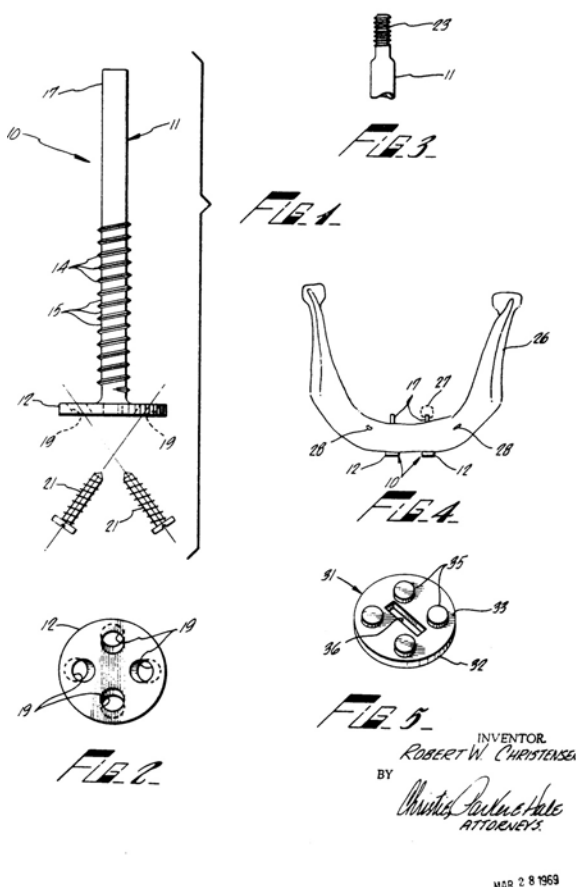


Fig. 2.9 From USP 3,474,537. Christensen's implant design relied on a caudal insertion path. The disk was not inserted into an enossal position but was covered by caudal bone growth in due course

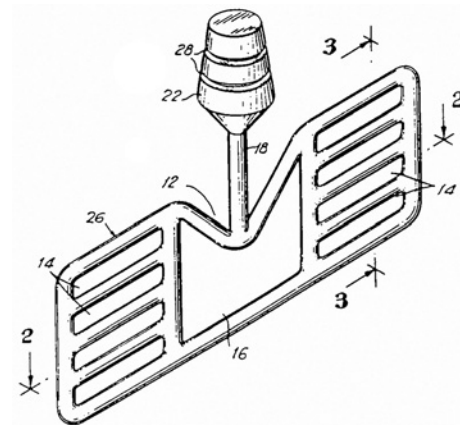


Fig. 2.10 From USP 4,768,956; skeletized implants in a blade design

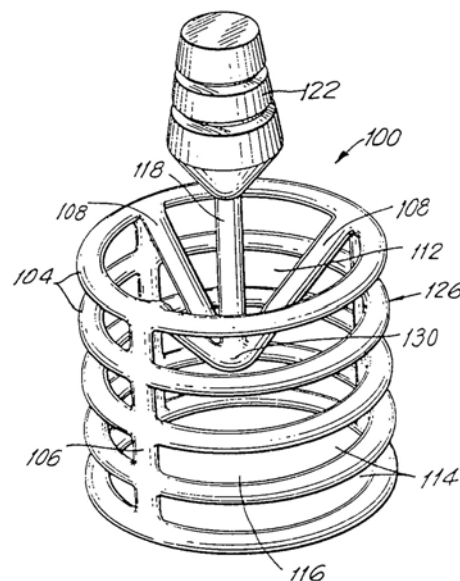


Fig. 2.11 Implant design of USP 4,768,956 in a basket configuration. Lateral insertion of this implant is prevented by struts 106 and 108

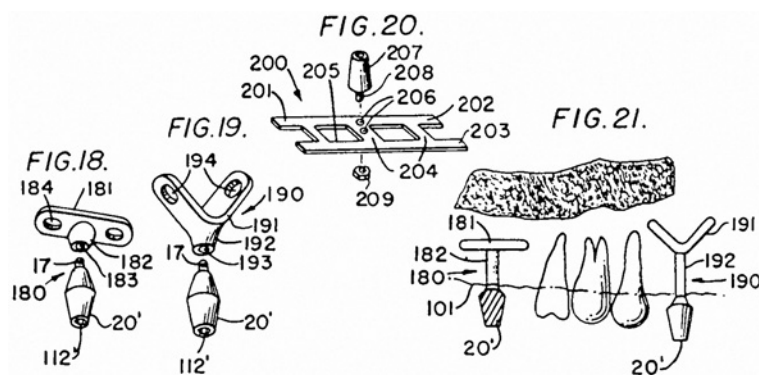


Fig. 2.12 Edelmann's bendable (adaptable) implants

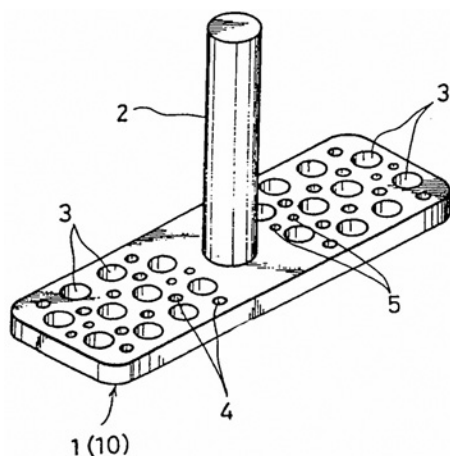


Fig. 2.13 Implant design with discontinuous surface, from USP 4,964,801

attention to the problem of the compromised blood supply above the implants. Inflammatory osteolysis vertically above the basal plate was a common observation, as the early implant designs were still better suited for use in the alveolar ridge. Complications of this type were caused by insufficient blood supply crestally to the disk, due to the fact that those early disks were not perforated. Based on current knowledge, the type of perforation specified by Kawahara was not up the challenge either and would have failed to ensure an adequate blood supply crestally to the basal plate just as well. Whether his implants were ever manufactured is unknown.

Scortecci's distribution company Victory (Nice, France) marketed two different implant systems. The "ED" series features an external thread (initial thread: M2×0.40; the subsequent version M2×0.25 is still state of the art) and delicate ribs along the shaft as thread markers. Available implant diameters were 5–15 mm. All implants have featured round disks and are available as single-, double-, triple- or even quadruple-disk designs. The distance between individual disks is invariably 3 mm. About 1990, Spahn

prevailed on Scortecci to produce "anatomically shaped" multi-disk designs, i.e. implants with multiple disks of different sizes. Two of those new implant types – EDD 12/8 G4 and EDD 15/9 G4 – have since been marketed and used in clinical practice with great success. They have come to be widely used particularly in maxillary restorations. Ideally, they allow quadricortical anchorage in the maxillary sinus, whose bony structure frequently has the shape of an inverted pyramid.

Better utilization of the cortical bone was also what three dentists at ITI had in mind when they presented an implant that included nails for retention. This design by Jürg Schmid, Christof Hämmerle (now a Department Head at the Dental School at Zurich University) and Nikolaus Peter Lang (currently a Department Head at the Dental School at Bern University) (1991) was basically a step in the right direction.

The inventors deserve credit for realizing that implants supported by lateral (cortical) bone would offer advantages in thin bone structures. Straumann AG has never implemented this design. They did not take into consideration the visco-elastic properties of bone and the concept of self-trabeculating as explained in Chapter 9.

The inventors barely missed the bull's eye on yet another occasion. A basal plate with an internally threaded cylinder attached to it was also specified in the German utility model application of 1994. Obviously, the spikes intended to offer anchorage in the bone can only be effective in the initial phase. Later on, they will invite load peaks and local osteolysis.

This design was in effect an "on-plant" rather than an "in-plant". In addition, it was intended to hold a membrane that would stimulate bone growth underneath. Given the scanty blood supply, it is reasonable to assume that a structure of this type would routinely lead to severe infections and eventually to the loss of the entire implant-restoration

CH 687 672 A5

Fig.1

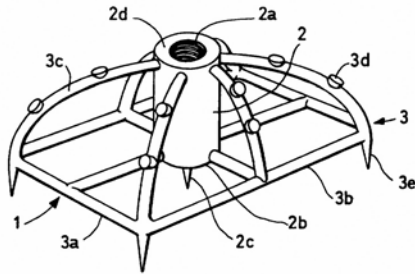


Fig.2

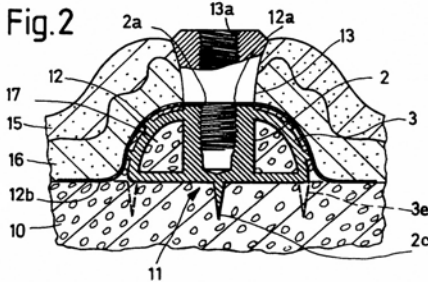


Fig. 2.14 CH 687 672 A5: The three-dimensional structure in Fig. 2.1 is designed to accept incoming loads without fracturing. The thin struts were hardly capable of handling masticatory loads in an adequate manner

Fig.6

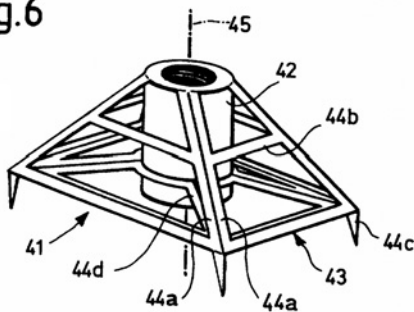


Fig. 2.15 From the same patent as in Fig. 2.14. Angled struts would presumably turn out to be very inappropriate in clinical practice. This implant design reflects a mechanistic mindset that is very detached from the realities of human biology. An implant of this type would be “extraterritorialized” from the very outset and stands little chance of being successfully integrated

complex. While the latter two developments bear no direct relationship to basal osseointegration, they do illustrate a specific mindset that was prevalent in a specific era. They illustrate how a group of scientifically committed dentists tried to work out solutions in which treatment planning would not be guided by the rules of biology and function but would expect human biology to yield to its own set of rules.

Meanwhile, a good and practical solution was developed almost simultaneously in various dental offices. K.-H. Müller applied for a patent for his double-unit design (1999), which included a threaded pin to be screwed to the basal plate. The principal objective was to provide anchorage for restorations along the maxillary sinus. Müller’s idea to place the basal plate inside the maxillary sinus but below the Schneiderian membrane was brilliant and farsighted. Using this concept, the residual bone volume under the sinus will be protected against infection and will even be preserved if the implant is lost. The inventor stated that he had been led by theoretical considerations without ever using those implants himself. Some aspects of this new concept had been used previously in the clinical work with single-unit BOI implants.

About the same time, Spahn applied for a patent on a multi-unit implant system featuring screw connections and a multi-threaded pin (1999).

Ihde and Spahn had laid the foundation for basal osseointegration even before that time, by applying for a patent on the first elastic implant design, thus turning away in theory and practice from the rather mechanistic theory of crestal implants and rigid bone-implant-prosthetics systems.

The basal plates were configured to match the anatomical shape of the jawbone, and the crestal plate was placed in a more resilient position than the basal plate. By virtually eliminating the risk of crestal osteolysis in the maxilla, this development can be regarded as a milestone in the history of BOI. At the same time, load transmission in the area of the crestal plate was confined to the palatal bone, which apparently was much better suited for this task in terms of structure, resorption tendency and blood supply than the vestibular bone.

By 1998, Spahn and Ihde had not definitively arrived at the conclusion that load transmission in the area of the threaded pin was altogether unnecessary. Therefore, the early implants of these series would still feature the rib-style surface enlargement described by Clunet-Coste. Those designs, in effect, marked the transition from crestal to genuinely basal implants.

The feature of a surface-enlarged shaft was eliminated only 1 year later when the Swiss patent specification CH 690 416 A5 was submitted as a corollary to EP 99 250 289.8.

More recently, further improvements have been added to the macro- and micro-design of the load-transmitting areas and to the transition zones towards the non-load-transmitting framework areas.

Conclusion. The idea of basal, wide-area support for implants was taken up by many developers at some point. In many of the patents and patent applications

quoted here, the resolution of situations in which insufficient vertical bone volume was available was what gave rise to the various ideas. Other developers were more interested in utilizing the harder cortical

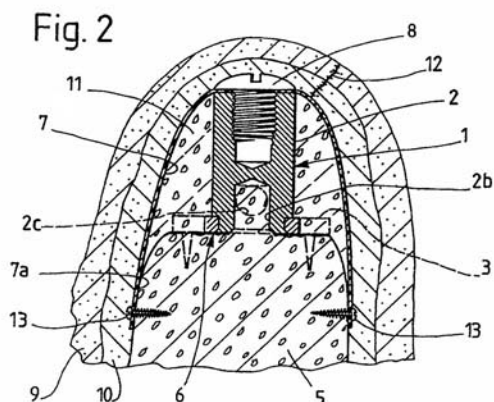
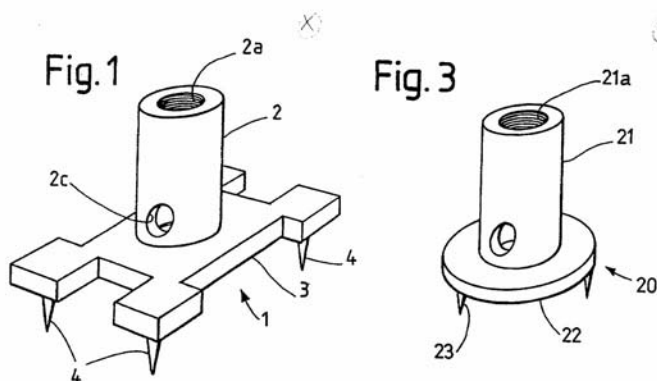
bone tissue also for immediate loading procedures. Only Juliet (1972), Scortecchi (1985) and Ihde (from 1998) ever turned their ideas into successfully marketable and clinically practical products.

Institut Straumann AG

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Fig. 2.16 Implant design featuring an internally threaded cylinder, a spiked basal plate and a membrane intended to stimulate bone growth



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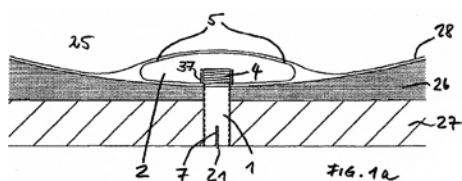


Fig. 2.17 Müller's double-unit implant was anchored inside the maxillary sinus and featured several insertion points for the threaded pin. The more recent Disktrack system was modelled after this design. There were no legal obstacles to this development because Müller had never followed up on his patent application

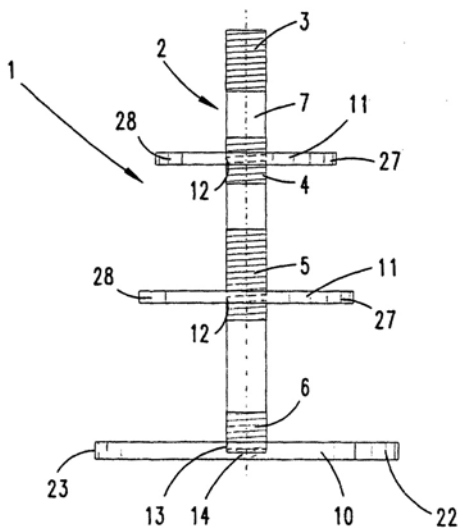


Fig. 2.18 The threaded pin comprises several “storeys” to which load-transmitting plates of different shapes can be attached. In contrast to the later development of distractor implants, Spahn’s design had always relied on pre-cut insertion pathways matching the disk-to-disk distance. Distractor implants are inserted by separating bone compartments for rearrangement at a later time, which is not the case with Spahn’s design

EP 0 935 949 A1

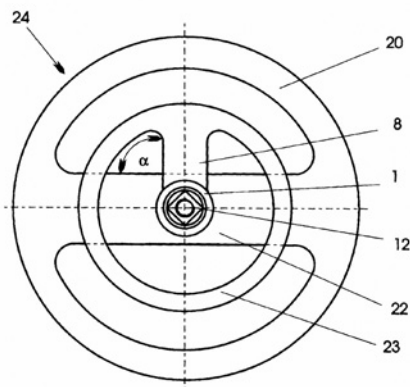
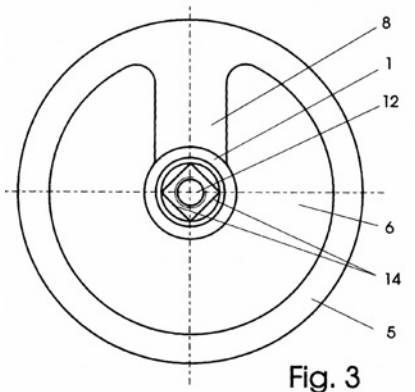


Fig. 2.19 Ihde and Spahn, in a collaborative effort, developed implants that behaved elastically inside the bone, allowing resilience of the threaded pin. In this way, the dogma that all enossal implant segments needed to be “osseointegrated” in a static way was broken. The construction of these implants enabled the transmission of unequal parts of the load to both basal plates. The basal plate was designed to be more rigid than the crestal plate. Hence a larger amount of the chewing force was transmitted through the lower plate while the crestal plate provides initial stabilization. It is necessary to remember that it is invariably the basal portion of the implant body that will transmit force in all implants in the long term. If dentists are shown FEM analyses or photoelastic stress images of implants embedded in Plexiglass in “scientific” studies, they will always show local stress peaks in the collar region of the implant. But these studies or images do not reflect the true situation. Unlike the Plexiglass model, live bone can avoid these stress peaks. There are several mechanisms at work to achieve this, such as changes in the relative level of mineralization by redistributing 0-areas and 1-areas. If the stress peak were actually located in the collar region, this would result in massive mineralization, and we would never see the crater-style bone collapse characteristic of crestal implants

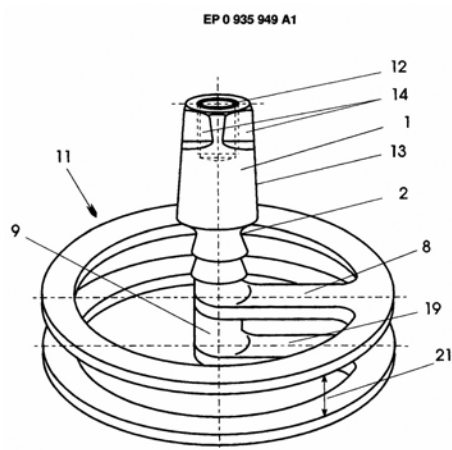


Fig. 5

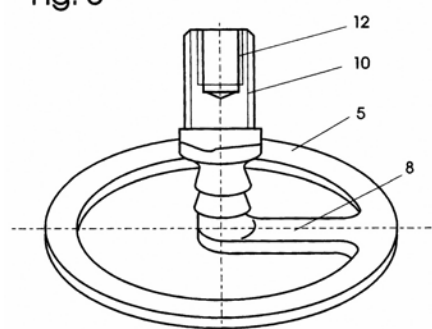


Fig. 6

Fig. 2.20 Surface enlargement along the shaft in otherwise resilient implants. This design has been especially successful in rigid types of implant-restoration complexes

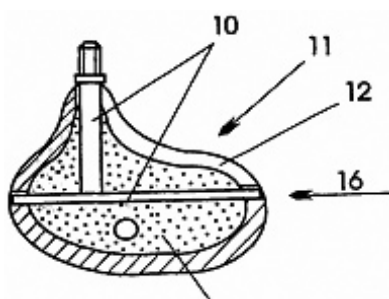


Fig. 2.21 This asymmetrical BOI implant design, first described in 2000, was capable of compensating for the centrifugal resorption pattern of the mandible, while the bone cavities for insertion could still be prepared with rotationally symmetrical instruments. Arrow 16 indicates the insertion path. The threaded pin is located away from the central position on the implant base, but offset (USP 6,402,516 B2). This design allows coping with the centripetal resorption of the upper jaw as well as with the centrifugal resorption of the distal lower jaw

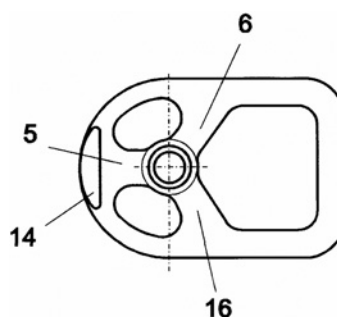


Fig. 2.22 BOI designs with three web bars have less resilience than designs with only two web bars

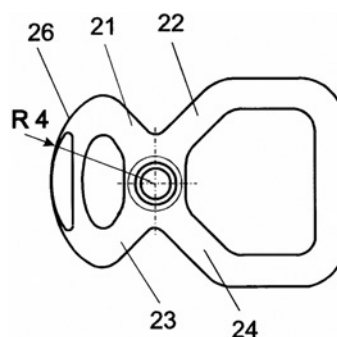


Fig. 2.23 Framework structures featuring four web bars are even more rigid. The mechanical weak points are located in the peripheral area. Note that implants with one round (left) and one square (right) end may occasionally give rise to increased osteolysis when the underlying bone structures at the three insertion points are not biomechanically synchronized and do not share the same degree of mineralization. Therefore the insertion of these implants must be more carefully planned. The three points are located at the “edges” or cortical “endpoints” of the implant: one edge is located at the round side, while the opposite side contains two edges

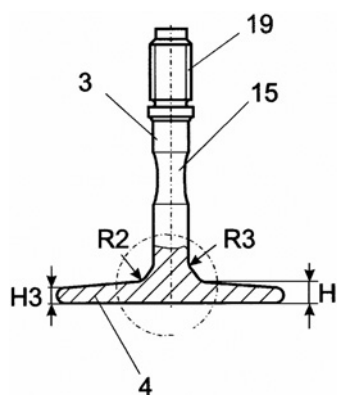


Fig. 2.24 Exact FEM studies resulted in fracture-proof geometrical configurations that helped to prevent notch stresses in high-load areas

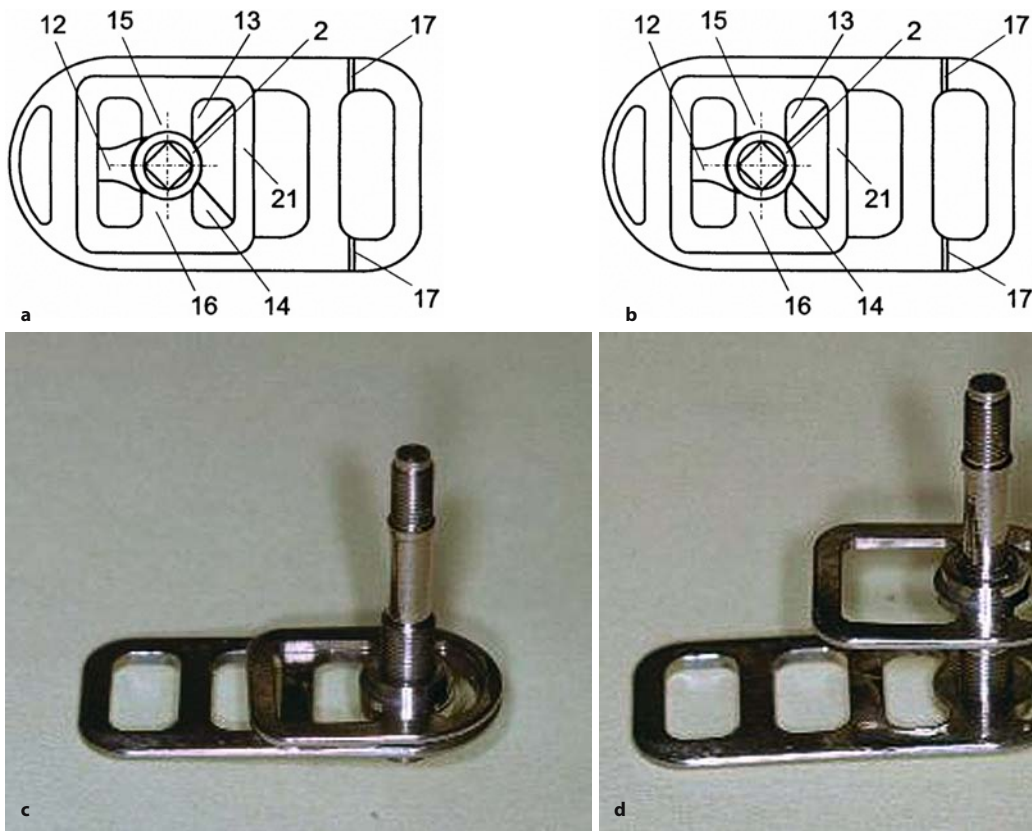


Fig. 2.25a-d Implants with disks that could be moved against each other after insertion, allowed treatment even in cases of small vertical bone supply whilst the restoration is in situ and loaded

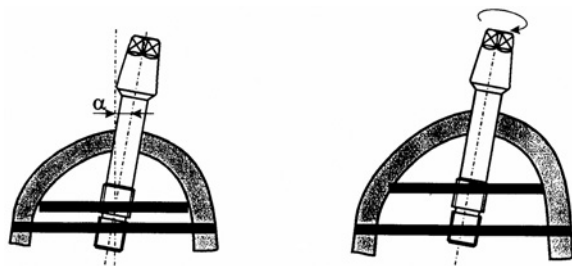


Fig. 2.26 Mounting the threaded pin to the basal plate at an angle will move the bone in a specific direction. Left and right = before and after distraction

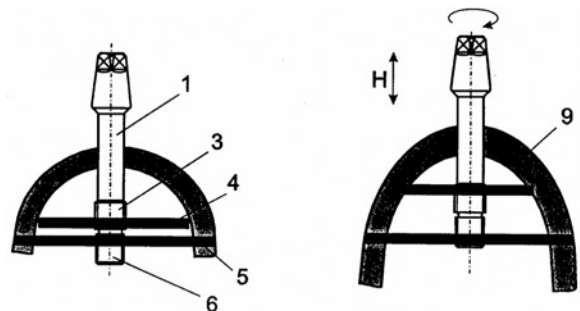


Fig. 2.27 A threaded pin featuring two opposite threads will minimize occlusal imbalances during the phase of elevation and thus reduce the need for occlusal adjustments. Left and right = before and after distraction

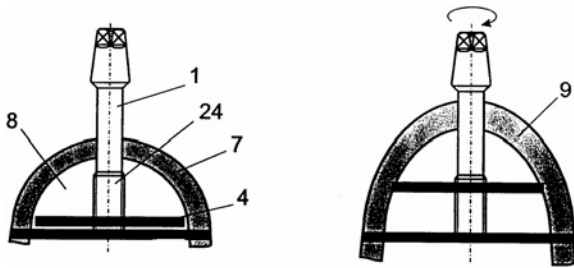


Fig. 2.28 A threaded pin featuring one thread only will result in a more pronounced elevation of the crestal bone segment than the design shown in Fig. 2.29. There is a greater need for occlusal adjustments. Left and right = before and after distraction

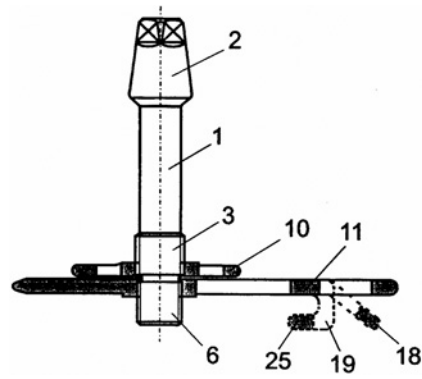


Fig. 2.30 BOI distractor featuring a foldable basal disk

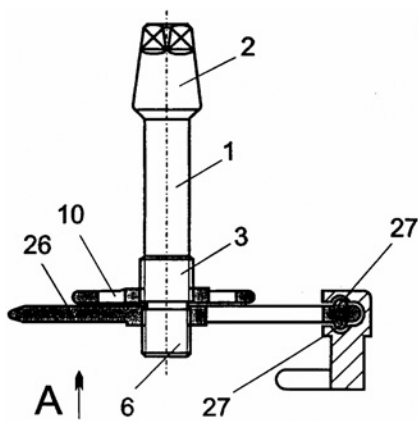


Fig. 2.29 To stabilize the basal plate, an additional (optionally detachable) strut can be mounted, or a foldable design of the vestibular implant segments can be used (as shown in Fig. 2.32)

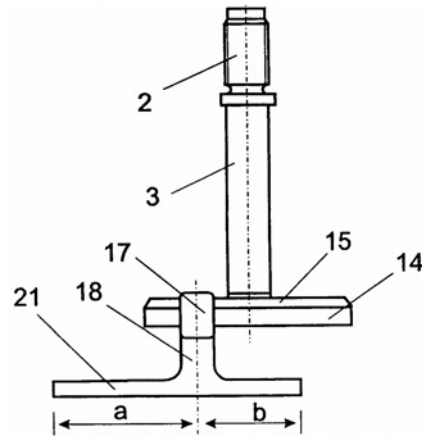


Fig. 2.31 One advantage of the detachable basal plate was that the bone utilized for stabilization did not have to be directly below the basal disk, but more lateral bone structures could be used as well

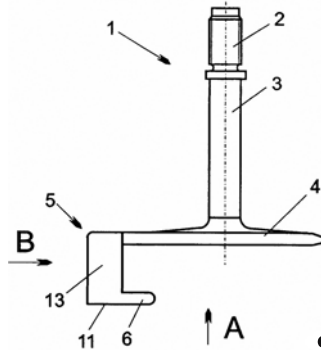
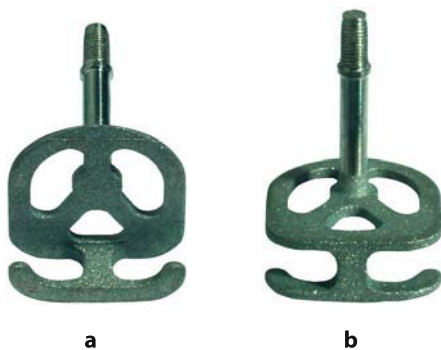


Fig. 2.32a-c Single-unit BOI designs featuring a vestibular partial disk are used if the vestibular bone in the maxillary posterior segment lacks in quantity or is susceptible to fracture. Another advantage is that there is no need for both disks to fully transverse the maxillary sinus, which improves surgical precision

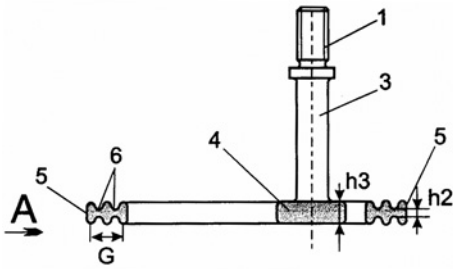


Fig. 2.33 Macromechanical surface enlargement (corresponding to the thread of a screw implant) along the load-transmitting areas was introduced to replace micromechanical surface enlargement. The need for sandblasting all the load-transmitting areas was thus rendered obsolete, which minimized the space for bacterial microretention. This increased the therapeutic spectrum for implants along the maxillary sinus and for single-step procedures in periodontally involved areas

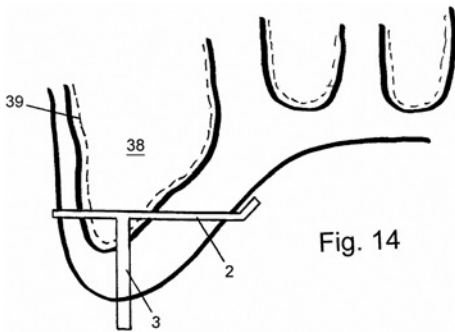


Fig. 14

Fig. 2.34 Trans-sinus implantation using single-unit BOI implants was first mentioned in USP 10.163.064. Any procedures for bone augmentation could be completely avoided with this approach. Trans-sinus implantation reduces both the duration and the cost of treatment. Hipbone grafting and similar augmentative procedures have become redundant (except in the aesthetic zone)

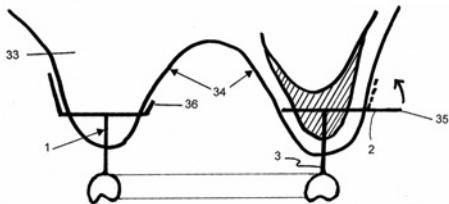


Fig. 12

Fig. 2.35 USP 10.163–136 first described both alternative implantation techniques (with or without intra-sinus augmentation). Some users still prefer the augmentative approach. At the same time, they report some losses of implants and of augmentation material inside the sinus, particularly in the region of the first molar and if extraction was performed in the same surgical procedure. The drawing illustrates that BOI implants can be readily inserted even in sinus areas that have been augmented previously (usually elsewhere)

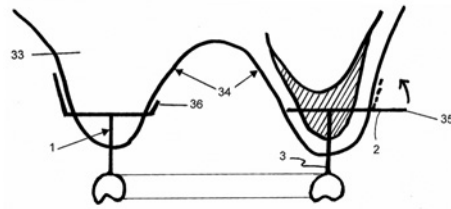
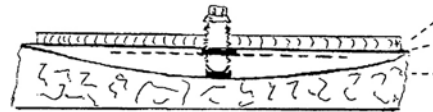


Fig. 12

Fig. 2.36a,b Drawing on BOI, Fuchs und Chierny (DE 102 12 815 A1; filed 22 March 2002) developed a distractor with a cardan-style advance mechanism. The large recesses in the basal plate indicate that these tools could also be left for use as implants



Figur 2

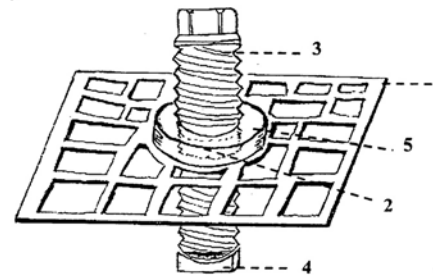


Fig. 2.37 A subperiosteally supported distraction device was specified in DE 199 07 420 A1 (Graf et al. 1999) that combines some characteristics of distractors and of BOI. This is one of the few patent applications in dental implantology that was filed from within a University Department

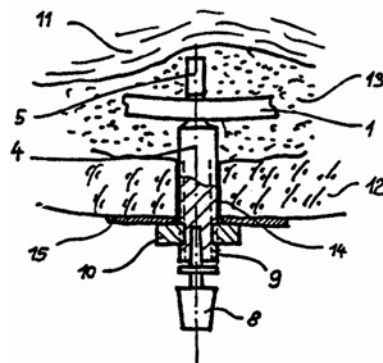


Fig. 2.38 The Austrian maxillofacial surgeon Katzenbeisser (1989) applied for a similar patent. This type of patent allowed lifting the sinus membrane in a two-stage procedure, with a horizontal base plate connected to the vertical implant part in a two-piece design

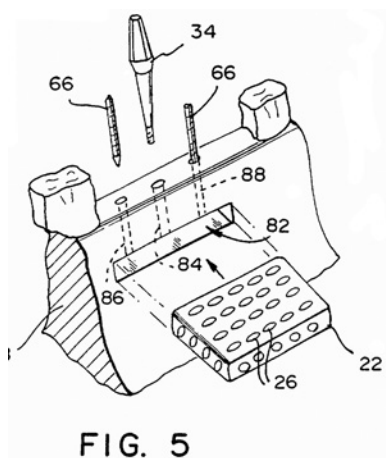


Fig. 2.39 Ashkinazy (1998) applied for a U.S. patent in which he presented the modular composition of an implant. In addition to modular crestal implant designs (including a blade implant with lateral cortical support by additional pins), a lateral implant with the same design was also presented

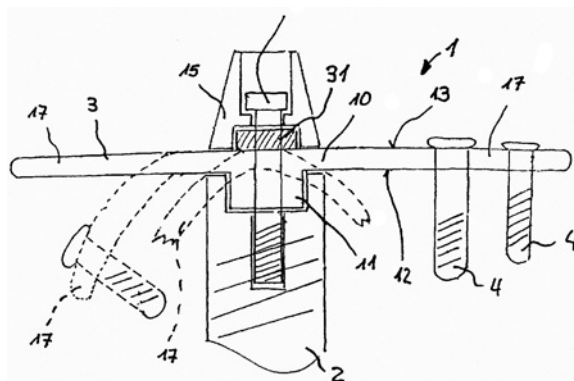


Fig. 2.40 Engelke (2000) is one of the few researchers and inventors from academia to be listed in connection with the overview in this chapter. He, too, recognized that only good cortical support offers sufficient primary stability. Since the term “subperiosteal implant” has slightly dubious overtones in the German-speaking countries, Engelke designated his implant as “subgingival”. Nonetheless, the lateral terminators that can be adapted to the jawbone are in fact subperiosteal aspects of the implant. Similar to bent BOI implant disks, they may be adapted to the shape of the jawbone or even screwed down. If sufficient elastic material is used, integration of this implant is conceivable. One would have to note, however, that large implants of this type would require mechanical synchronization of very different regions of the jaw

Morphology of BOI Implants and Related Designs

Chapter 2 provided an overview of the different types of lateral implants devised, introduced and employed over the past 30 years. The present chapter will provide the reader with the necessary background to understand the differences and commonalities of these designs, as well as their applications in clinical practice. Today it is almost impossible to draw a clear line between «disk» implants and BOI implants. Over the last few years in particular, the similarities between those designs have increased in various ways. The same development has also taken place in crestal implantology. While implants of the Diskimplant type are basal implants and while they take into account the concept of bicortical support, these rigid Diskimplants do not implement the concept of isoelasticity with the bone to the same extent of actual BOI implants with a skeletal design.

3.1

Morphology of the Threaded Pin

The term «threaded pin» denotes the implant segment connecting the disk(s) to the element retaining the prosthetic superstructure. It was introduced deliberately to describe the function of this vertical component, which implies that other tasks, such as direct enossal load transmission, are not part of its function. It is therefore irrelevant whether the threaded pin becomes fully «osseointegrated», whether it becomes only «osseoadapted» or whether it becomes embedded in connective tissue. The exact manifestations of successful integration may vary widely, as the reader will learn later in this book (see Chapter 23).

Scortecci equipped the ED implant series with rib-style depth markers along the shaft, which offered useful guidance especially for beginners, since the task of advancing the implant to the anatomically correct depth of the basal ridge may be quite difficult in the hands of inexperienced surgeons. On the other hand, depth markers would actually be more useful on the cutter rather than on the implant because, no matter how well they are designed, they invariably add to the risk of plaque retention and infection. Eventually, this can sometimes result in crater-style

bone collapse. This eventuality is well known to be associated with vertical load transmission surfaces. Therefore, what may be an advantage in the early phase of treatment may turn out to be a disadvantage in the longer term. These considerations have prompted us to abandon the use of these markers.

The distances of 1.5 mm between the ribs on the implant were originally intended to allow the operator an assessment of the length of the implant required. Although BOI implants and internal disk implants come with completely smooth shaft surfaces today, the length of the threaded pin is still measured in «G» units: 1G=1.5 mm. With an implant of length G5, the distance between the crestal disk and the beginning of the external thread is thus 7.5 mm.

Considering that niche organisms such as bacteria (or osteoblasts and osteocytes) will preferably colonize surfaces that feature macromechanical spaces, it definitely makes sense to use threaded pins with a completely smooth surface. Roughened surfaces in the mucosal penetration area may in the short term enhance osseointegration. Taking the long perspective on implant lifetime, this feature of the implant will invite bacterial attack. Enossal implant surfaces are just as likely to become a dwelling ground for microorganisms as root canaliculi (capillaries). Note that anything that benefits osseointegration will also benefit microorganisms, since surfaces are competitively occupied by osteocytes or by bacteria. Deep inside sterile bone structures, the osteocytes will usually prevail. In the immediate vicinity to the ever-infected oral cavity the bacteria have a better chance of survival because they are growing much faster, adapt better to highly perfused and oxygenized soft tissue and thus behave more aggressively and successfully.

Once the infection has reached the implant surface, colonization will relentlessly take its course. It is virtually impossible to control peri-implantitis on rough surfaces.

In addition, single-step procedures in which extraction and implant placement are performed in the same session favour such colonization due to the incongruent surfaces involved, i.e. the gap areas are preferred sites of rapid colonization.



Fig. 3.1. This ED 10 G6 implant lacks bone apposition down to below the threaded pin. At the time the picture was taken, the implant had been in situ for 5 years. The load-transmitting segments are in full function. The implant is located in too high a position (low G value). Particularly at the anterior aspect, it almost falls short of the white line of maximum load transmission, indicating that the implant is unlikely to survive in the longer term. This example clearly demonstrates the interaction between bacterial attacks and the functional tendency to preserve peri-implant mineralization. In this specific patient, the conditions for bacterial attack were particularly favourable, due to very poor oral hygiene, rough vertical implant surfaces, elasticity of the implant-restoration complex, and heavy smoking



Fig. 3.2. The transition from “disk implants” to BOI implants was marked by a period in which implants with dual load transmission were the state of the art. In this design, load transmission was supposed to take place both in the vertical and in the basal implant part. These implants are perfectly serviceable if the behaviour of both the vertical and the horizontal bone structures used for anchorage are mechanically synchronized with the implant surface. This is mainly the case in the anterior segment of the mandible. The ribs are 1.5 mm apart and represent the G graduation

Attempts to achieve optimal integration of the vertical implant segment by combining macroscopic

steps and microscopic surface enlargement by sandblasting have led to better clinical results in terms of initial healing. Permanent osseointegration can even be obtained along the vertical implant segment, provided that the number of implants placed in each arch is adequate and that the design of the bone-implant-restoration complex is sufficiently rigid. Counteracting forces include elastically intruding occlusal forces, functional shearing loads, unbalanced extrusion forces, and flexion of the jaw at large. The latter may amount to several millimetres and can be readily measured, especially in the mandible. These counteracting forces lead to mobility at the implant-bone interface, thereby jeopardizing the close osseointegration of long threaded pins. In the presence of surface-enlarged threaded pins elastic micro-movement (Ashman and van Bushkirk 1987) may irritate the connective tissue structures and, at the same time, support inoculation of the bacteria residing on the roughened surfaces. Any infections in the wake of bone avulsion that are capable of advancing to the deeper bone segments will result in crater-style osteolysis. While collapses of this type do not necessarily impair the function of the implant (Fig. 3.1) as long as the force-transmitting disks (notably the basal disk) remain intact, they are nevertheless undesirable. Roughened implant surfaces close to the oral cavity involve a greater risk of bacterial retention. Moreover, resilient implant-restoration systems seem to result in mechanical irritation by mobilizing the surfaces of the threaded pin and the bone against each other. Such irritation is also likely to reduce the chances of reintegration should the implant become mobile itself.

The tendency to reduce the number of implants for bridge restorations originally arose from cost considerations and considering biomechanics. In accordance with that tendency, the transition from the first disk implants to true BOI designs was gradually made. After all, the bridge spans and the associated positional changes between abutments increased as the number of implanted abutments decreased. In other words, the mutual mobility of the abutments became greater, which was not per se inconsistent with good stability by basal osseointegration. The threaded pins were subjected to a higher degree of deflection, which caused the implants to intrude deeper into the bone and mucosa creating friction. The hard-tissue irritation associated with the intra-bony movements involved a risk of vertical bone loss along the threaded pin. When BOI implants with a smooth shaft were introduced, the threaded pin will recede into the associated hard- and soft-tissue structures without causing any noticeable irritation or bacterial inoculation. Ultimately, this structural detail prepared the ground for comprehensive implant therapy along the maxillary sinus, where

the therapeutic spectrum had hitherto been limited. Furthermore, large distances between the threaded pins made it unlikely for the peri-implant bone to behave mechanically in synchronization with the threaded pin. Such behaviour would have been required if osseointegration of vertical implant segments needed to be maintained. The function of the vertical implant segments has since been largely reduced to compensating for motional differences between the integrated disk areas, since these would never quite behave synchronously. The bridge itself became the fixed reference point within the masticatory system; however, unlike with crestal implants and teeth, the pontics of BOI-based bridges (especially in strategic positions and with few basal plates) are no longer directly connected with the fate of the alveolar bone.

To summarize: the direction that has eventually led to genuine BOI systems was initially defined by Scortecchi's implant designs featuring depth markers and surface-enlarged shafts. The literature and thinking associated with crestal implantology used to be so persuasive that all designs for enossal implant segments would feature micro- and macromechanical surface enlargement for a long time. More recently, hybrid designs were developed in which the shaft segments near the mucosa were smooth and the basal segments were roughened for surface enlargement. These were the first designs to offer true basal osseointegration and strategic abutment positioning, using only four implants per jaw.

As will be demonstrated elsewhere in this book, overgrowth of subcrestal implant segments by connective tissue does not irreversibly prevent osseoadaptation. By contrast, subsequent osseoadaptation or osseointegration is no longer a realistic expectation once bacterial infection has spread to an osteolytic area, which is presumably due to the associated granulation around the implant.

With the smooth-shafted designs available today, implant treatment along the maxillary sinus can be readily performed by placing the disk and part of the threaded pin inside the sinus. Trans-sinus implant placement becomes unavoidable if the vertical bone volume caudally to the sinus is small and the expected changes in the intra-bony trajectories are also small. In this situation, intrasinus implantation is a better biomechanical option. The use of crestal implants would involve adjuvant procedures for sinus floor augmentation to facilitate load transmission along the entire vertical portion of these implants.

3.2

Load Transmission by Disks or Rings

The crestal and the basal plate of multi-disk elastic implants used for basally osseointegrated implant-restoration systems have different functions. The main purpose of the crestal plate is to provide additional stabilization of the implant. The crestal plate loses its importance once the basal plate has ossified to full load-bearing capacity. Since the crestal and basal plates of the former "disk implants" were equally resilient against the threaded pin, an estimated 10–15% of these cases had to be followed up by subsequently removing the crestal plate. Unless this was done soon, there was a risk of infection and osteolysis advancing from crestal direction. Once the infection was impacted in the submucosal or intraosseous area, there was a risk that it would eventually advance to the basal plate, so that the entire implant was eventually lost.

One of the most useful developments of the past few years has been to improve the resilience of the crestal plate in relationship to the basal disk. In new BOI implants, the web bar of the crestal plate is located perpendicular to the web bars of the basal plate. In other words, this part of the crestal plate is inserted directly into the palatal bone, well protected against resorption.

The osteotomy area in the vestibular bone, by contrast, is crossed only by the ring of the crestal plate. The ring acts like a tent keeping the periosteum away from the bone, thus facilitating any primary or secondary augmentation procedures.

3.3

Distance Between Crestal and Basal Load-Transmitting Surfaces

Double/multiple disk implants have been available in France since around 1988. The disk-to-disk interval on these implants is 3 mm. Specific double cutters matching these distances for lateral osteotomy are available. We have since, in collaboration with Spahn, introduced implants and osteotomy tools for 5-mm disk-to-disk intervals in our clinic.

This modification was prompted by our observation that the room for manoeuvre inside the bone was very small whenever the need for surgical removal of crestal plate arose. This lack of space involved a high risk of intact bone being engaged or, indeed, damaged by surgical instruments. These manipulations in the area of the crestal plate have now become easier whenever the need for corrective intervention arises in cases where the newly introduced designs with the larger disk-to-disk intervals were used.



Fig. 3.3. A configuration in which both disks having the same thickness and featuring two web bars each will result in an unequal distribution of functional loads, i.e. the crestal disk is subjected to greater forces than the basal disk. Consequently, the crestal disk will be more susceptible to overload osteolysis, in which case the basal disk will still remain osseointegrated for the time being. In fact, the greater risk of osteolysis around the crestal disk is also a function of its greater rigidity compared to a basal disk of the same thickness. Put differently, it does not even take an unbalanced force distribution to increase the risk. Some users have severed one web bar of crestal disks prior to insertion in order to make them more elastic



Fig. 3.4. The crestal disk in today's BOI designs includes only one web bar, which offers a greater degree of resilience at the crestal than at the basal disk. The crestal disk is inserted with the web bar facing palatally, such that the incoming forces are guided right into the palatal bone, which is protected against resorption. This is in contrast to the basal plate, where incoming forces are distributed throughout the ring in accordance with the biomechanics of the cranial bone where both the vestibular and the central bone structures are equally well protected against resorption. The picture illustrates the polished crestal segments and the small diameter of the threaded pin (< 2 mm)

There was yet another consideration that led to this modified design. For the bone surrounding the disks to be functional in terms of load transmission, an adequate blood supply has to be present. Implant structures will impede or disrupt the blood supply. This shortcoming became clear in the 1980s when the first series of “disk implants”, which featured inadequately thin microperforations in the basal plates combined with short threaded pins, were frequently lost because of poor conditions in terms of blood supply and immune defence crestally to the disks. An adequate blood supply is decisive for long-term survival of BOI, which specifically applies to the area of the crestal disk as well. Ever since we were able to insert BOI implants featuring the larger disk-to-disk intervals of 5 mm, we observed that both basal plates integrated evenly well. As will be shown in Chapter 23, the formation of secondary osteons around one of the basal plates does not seem to interfere with similar formations on the other basal plate. Also, the nutrient supply for each basal plate is assumed to be larger if the disks are located further apart. Problems with implant-restoration systems supported by this type of implants are extremely rare. This is even true of those cases in which only a single one of these implants could be inserted (usually to replace an upper canine).

3.4

Shape of Basal Load-Transmitting Surfaces

When rotationally symmetrical disks were used in implants, close inspection of those designs would reveal that they were only congruent with the bone structure on the insertion side facing away from the osteotomy pathway. On the vestibular side, the disk did not fill the entire osteotomy pathway but left a gap in the bone that would not close until ossification in the healing phase was completed. The situation was compounded by the fact that the crestal side of the vestibular ring segment was not covered with bone if the osteotomy was perpendicular to the bone surface. It was assumed that this might cause healing problems.

To remedy this situation, the next generation of disks had a flattened rectangular design on one side and remained rounded on the other side. In the first implants available with this design, the greater distance from the disk rim to the threaded pin was confined to the rectangular area. Users would refer to these implants as “S” designs. The “S” has since become an established part of the identification code used for any BOI-implant type featuring at least one flattened side. Experienced users also apply these implants with the flattened side facing not towards the vestibular but the medial aspect and take advantage

of the asymmetrical position of the threaded pin. This approach is advantageous if the vestibular bone structure is characterized by extreme resorption and the main burden of load transmission has shifted to the medial bone structure. Even if it is not intended to place the pin towards the medial aspect (e.g. with EDAAS implants), the flat side of the disk will automatically face towards the palatal side when this approach is used.

Perforated implants disks are a *conditio sine qua non* because the communication between the adjoining bone structures in the crestal and basal area would be overly disrupted in the presence of closed-surface disks. Uninterrupted baseplates would also impede the blood supply to the more crestal structures, thereby causing early implant loss and massive bone loss. Last but not least, large non-perforated implants would contribute to the pathogenesis of sarcomas (Ott 1970; Nothdurft 1961).

3.5 Structural Resilience of Implants

Elastic behaviour of individual implants within the same implant-restoration complex is also an indication that these implants may not perform their load-bearing function as they should, since there is always a chance in this situation that they may yield to functional loads by elastic bending. The loads would then shift to any other implants within the same complex, which may be substantially more rigid. Sometimes these additional loads may be excessive. This mechanism needs to be taken into consideration. The concept of strategic implant positioning implies that a limited number of implants



Fig. 3.5. Implant featuring a wider disk-to-disk interval of 5 mm



Fig. 3.6. **a** Heavily skeletonized implant of the EDDS type. The basal plate includes two web bars; the crestal plate includes only one bar and is substantially more resilient. The threaded pin is machined above the crestal plate; all other surfaces are sandblasted. The extraordinary resilience of this implant type is apparent; compare to Fig. 3.4. **b** Triple BOI implants with small disk diameters are much more rigid than implants with fewer disks and larger diameters. BOI implantologists can therefore choose not only between implants in many different sizes, but can also select according to the resilience of the implant

will be subjected to substantial forces. Overly elastic implants within such a system may be a disadvantage particularly in the maxilla. In the mandible, by contrast, greater lateral elasticity is actually required for full-arch restorations.

3.6 Configuration and Relative Dimensions of the Implant Components

The diameter of the basal disk in BOI implants should preferably be as large as possible to meet prosthetic requirements. From the BOI implantologist's viewpoint, implants featuring a load-transmitting basal plate of less than 9 mm in diameter (particularly

those with a thickness of 0.6 mm or more) must be regarded as rigid. Implants with a larger disk diameter are more elastic than implants with a smaller-diameter disk of the same thickness. Even more important, the load-transmitting surfaces of these implants are located farther away from potential infection sites or infection entry points. This, after all, is the ultimate criterion for the long-term survival of implants.

Put differently, the distance between the load-transmitting surfaces and the site of bacterial attack can be increased by using a large-diameter disk. An alternative option would be to select an implant with a longer threaded pin. Note that modifying the length of the threaded pin may critically alter the lever configuration.

The web bars connect the disk(s) to the threaded pin. The shape and size of these bars depends on their function of converting functional loads to isoelastic vibrations and cyclic loads that the supporting bone can tolerate.

The bars should be resistant to fracture and capable of force distribution over larger bone areas to avoid osteolysis by local stress concentrations.

In order to simplify the storage of implants until use, designs with more than one web bar were developed. These designs have been known as ADS implants. For example, an EDADS 12/17 G7 could be used in two different ways: either as a regular 12×17-mm implant by removing the additional bar, or as a 12×15-mm implant by removing the ring segment beyond the bar. The necessary adjustments were performed intraoperatively with a tungsten carbide cutter. Another popular design is the EDADS 9/14 (G5–G7) design. Note that only one web bar must be removed to maintain the integrity of the ring

structure needed for optimum load distribution of the disk. Disruption of this structure would result in local stress peaks along the implant-bone interface.

3.7 Surface Areas of Implants

Enlarged or smooth surfaces in specific implant segments may be an advantage or a disadvantage, depending on the clinical situation. For that matter, what may appear to be an advantage initially may turn out to be a disadvantage in the long term. This possible consequence became evident at a time when the surface of crestal implants would commonly feature TPS (Titanium Plasma Sprayed) coating. Those implants were sprayed with titanium particles at high temperatures, which resulted in extremely rough surfaces with lacunae between the particles. These surface properties offered excellent conditions for bone adhesion and primary stability. Unfortunately, they favoured not only adhesion of bone but also bacterial retention. Whenever infections came to pass, the ground was prepared for bacteria to colonize the lacunae between and under the TPS particles as “permanent residents”. Therefore it was often necessary, when infections occurred, to mechanically strip the implant of its top layer, ideally all the way down to the bone.¹

Sandblasted surfaces are almost as rough as TPS-coated surfaces, but they can be effectively washed and ventilated, which is enormously helpful in eliminating peri-implantitis. Implant surfaces that have not been sandblasted are the easiest to clean, but they offer less retention for microanchorage within the bone than enlarged surfaces. Completely smooth surfaces were used in Brånemark implants from 1968 up to around 2000. While these designs were clinically very successful, they did not usually allow timely loading.



Fig. 3.7. EDAS 9/15 G5 implant. Due to the asymmetrical location of the threaded pin, around 75% of incoming axial loads will be transmitted to the rounded segment of the disk (right). The straight segment (right) will only have to bear the remaining 25% of the functional load. The implant can also be inserted the other way round if this distribution is considered inappropriate

¹ That Straumann went from TPS coating to SLA coating is remarkable in more than one respect. As late as in 1997, Buser had shown in a broadly designed study that TPS-coated full screws of the ITI type are extremely resistant. Nonetheless, Straumann abandoned this design and started marketing the SLA coating, without any equal study showing that the SLA coating is superior. It is hard to understand why a product is abandoned that had had “scientifically proven” success without first demonstrating the superior qualities of the successor product. To this day, many users cite the above-named study, a study that had been performed using completely different implants that are not even available on the market today and where only a single design feature still corresponds to the scientifically tested implant: the intraoral coupling design (internal cone and internal octagon). Good marketing allows the selling of a brand new product with proven long-term success!

The experience with screw implants of the Brånemark type has been that designs with smooth surfaces involve a higher rate of premature implant loss than TPS-coated designs of the ITI/Straumann or IMZ type. On the other hand, the latter two implant types have been associated with a considerable rate of peri-implantitis, gingivitis and peri-implant osteolysis. Large-scale bone collapses spreading from the implant collar in apical direction were a typical complication of these designs.

All-smooth surfaces in the crestal segment of the threaded pin are a standard feature of today's BOI designs. Surface enlargement, if any, is essentially confined to the load-transmitting disks, the web bars and the lower fifth of the threaded pin. Ever since we have used this configuration of smooth and roughened surfaces, the incidence of peri-implantitis has fallen dramatically. We never expected Brånemark-style load transmission or osseointegration to take place along the threaded pins of these designs. After all, BOI systems involve no need for any of this. Due to the smoothness of the threaded pin, the implant-restoration complex becomes more elastic. Non-authorized implantologists routinely misinterpret this elasticity, thinking that such restorations are in a poor condition.

Enlarged surfaces occasionally turn out to be a disadvantage on double-disk BOI implants with a disk-to-disk interval of 3 mm. Consider that the bulk of functional loads will be guided to the basal disk as the crestal disk is subjected to greater lateral forces, thereby losing contact with the bone in around 15% of cases. The enlarged surfaces may thus irritate the collagenous bone segments and potentially give rise to radiographically manifest osteolysis down the road. This process is non-bacterial and reversible in its early stages. It becomes irreversible only later once bacterial invasion has been allowed to occur via the threaded pin (Spahn 1992).

The appropriate treatment of such osteolytic processes is to remove the crestal plate as expeditiously as possible. In recent triple-disk designs, surface enlargement has been reduced to the two basal rings, while the crestal ring is left smooth.

In the French school of BOI, today's "Diskimplants" with internal threading are smooth all the way round (i.e. featuring no surface enlargement whatsoever), have been employed very successfully. The question whether these implants may be advantageous in a general way over the partially sandblasted designs that we use in our own practice has not been formally investigated. At least it would appear plausible that a smooth crestal plate may minimize irritations to the bony implant in case the plate becomes dislodged and mobile. Treatment of peri-implantitis would, of course, also be easier and more likely to be successful if the need arises. As a disadvantage, all-

smooth implants offer less primary stability against friction and especially rotation, which means that more implants have to be inserted (especially in immediate-load protocols) than would be necessary otherwise.

The risk of marginal osteolysis with ED implants featuring a smooth and thin shaft is negligible even in patients with poor oral hygiene, as impressively exemplified by the case reports in Chapter 8.

3.8

Elastic Versus Stiff Implant-Restoration Systems

The implantologist must decide whether to use more elastic or rigid BOI implant designs. The more basal plates a BOI implant has, the more rigid is its behaviour in the bone – and the larger the base plates at a given thickness, the more elastic is its behaviour. In rigid bone areas, rigid designs (e.g. triple-disk implants of the EDDD type) are an appropriate choice. They can be used in conjunction with other BOI implants or, indeed, crestal implants to support more rigid implant-restoration complexes, or they can be used as single-tooth implants to replace anterior teeth or premolars in the maxilla or mandible.

Crestal implantologists tend to deny the need for isoelastic behaviour of implants in situ. From the experience gained with screw designs, any visible mobility of the implant is undesirable. It is true that lack of primary stability is one of the main reasons for early implant loss with crestal designs. Crestal implantologists infer from this that the jawbone will grow towards implants for which primary stability has been achieved and propagate on their surfaces "voluntarily" or "intentionally", as it were, to prepare the ground for functional load transmission. As will be shown further below, one major incentive for bone remodelling comes from stimulation of neighbouring osteons on force-transmitting trajectories being disrupted in the process of preparing the implant bed. This mechanism has been described in the orthopaedic literature for decades. The implant itself mediates these stimuli only to the extent of transmitting functional loads and thereby creating force peaks in the early phase.

Clinical ankylosis of teeth is rightly regarded as a pathologic condition. It is therefore not entirely consistent for dental implantologists to postulate the same condition as a treatment objective in the case of implants. Osseointegration along the vertical dimension is an inherent requirement for crestal implants since they lack any horizontal components. It follows that these implants reduce the elasticity of the jaw. A designation like "root-shaped" implants is

purely formal in meaning and cannot change the fact that these designs lack essential characteristics of a natural root, elastic suspension being one of them. BOI implants are elastically suspended between cortical bone structures. In this way, they have much more in common with natural roots and the elastic features enable the restorative dentist to mount larger bridges on only a few implants per jaw. The advantage of elasticity is reduced as the number of implants supporting a restoration increases. Increasing the number of disks and the thickness of the shaft, bar and ring, however, will also reduce the elasticity of the overall complex.

The first generation of disk implants by Julliet virtually allowed no elasticity whatsoever. Although they were made from an elastic type of titanium, they were just too thick to afford the required degree of isoelasticity. Even the reinforced internal French Diskimplants (made from grade 2 titanium) were, and still are, suitable only for rigid multi-implant concepts. Scortecci demonstrated that rigid implant-restoration complexes could be established very successfully by inserting a large number of lateral implants even in combination with screw implants, completely neglecting the elastic properties of the jaw bones. On the whole, the history of basal osseointegration over the past 30 years has been characterized by a learning process driven by mutual input on the part of users and manufacturers. The textbook by Scortecci, Misch and Benner (2001) mainly shows rigid implant-restoration systems. Their multi-implant concept, while being a viable strategy in principle, does not justify the financial expense in many situations, and the large number of implants inserted does smack of “overtreatment”.

In our experience, four or five BOI implants will suffice to ensure stable restorations in the mandible. In the maxilla, a greater number of implants may be safer, taking the lower bone quality and high mechanical stress (e.g. by parafunction) into consideration. In quite a few cases, a greater number of disks per implant should be selected also. Combination with several crestal implants may be appropriate to ensure adequate stability of the structure. Furthermore, this approach allows for immediate loading in a greater number of cases. The conditions in the maxilla regarding the relationship between internal pressure and external (i.e. cortical) compressive/tensile stresses are not the same as in the mandible. Therefore, the implantologist should consider placing additional implants instead of strictly following the formal rules of strategic implant positioning. This applies especially to cases in which masticatory function needs to be re-established as well. A larger number of implants or disks per BOI implant is necessary if the width of the occlusal surface of the prosthetics is desired to be larger and provide cusps (see Chapter 10 for comments on those features of the superstructures).

3.9 Retention Systems for Prosthetic Superstructures (ED Versus ID Types)

In crestal implantology, three essential systems are used to connect superstructures to the inserted implant fixtures: cone connections, internal screw connections (either of the bridge or of the abutment), and direct or indirect cementation. Internal screw



Fig. 3.8a–c. The IDO system is based on the M2 internal threads, combined with external octagonal anti-rotation feature. The system is fully compatible with ITI implants. ED implants feature an external M2×0.25 thread. EB types are manufactured to contain the basal plates, the thread holder (which does not hold a thread in this case) and the abutment in one piece. Those implants are cheaper because it is not necessary to buy abutments

connections require the use of an internal thread, which may have different configurations depending on the implant type. To permanently resist functional loads, the thread must have a minimum diameter. In practice, M2 (or even M3) internal threads are used for reliable connections.

The French ID implants are used with M1.4 internal threads. They are used in combination with pure gold screws that plastically alter their shape in the process of screwing and are subsequently retained by a high degree of static friction. The clinical success of this type of screw retention is also due to the fact that it is usually applied in the presence of numerous implants.

External BOI implants have always used M2 external threads, regardless of manufacturer. The

thread pitches have diminished over time. The most usual pitch is now 0.25 mm. Some external BOI are still equipped with a 0.40 mm pitch and of course implant with M2×0.40 thread are still found in many patients. This must be taken into consideration when placing new prosthetics on older types of “Diskimplants” The term “*external*” BOI refers to the external (i.e. male) *thread* (Fig. 3.8b).

Internal BOI implants as used in France (ID-type designs according to Scortecchi) feature an external hexagon. Even so, the term “*internal*” refers to the *internal screw connection*. These designations are *not* consistent with the terminology used in crestal implantology.

Case Study 1

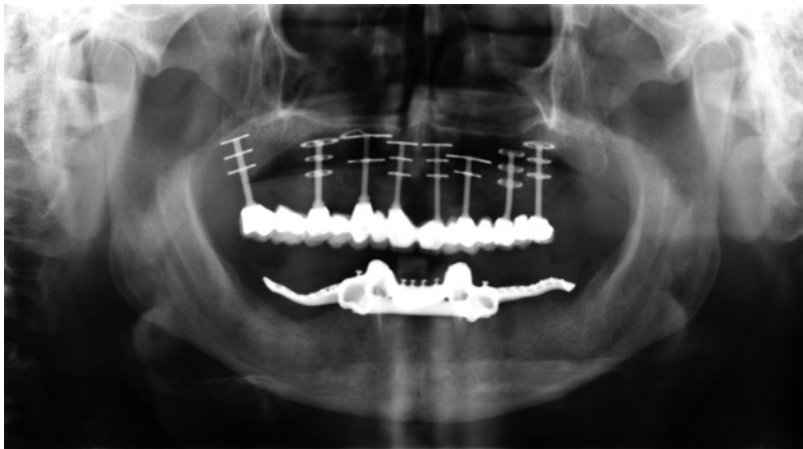


Fig. 3.9. Six triple-disk BOI implants and two double-disk BOI implants provide a stable basis for an immediately loaded full bridge for the upper jaw. All BOI implants have been placed immediately after the removal of four other implants. The bone-implant-restoration system is completely rigid; there are no resilient elements. In the area of the upper right third molar, a triple-disk BOI implant was placed in an oblique direction, using the same bone areas a tubero-ptyergoid screw would

Case Study 2

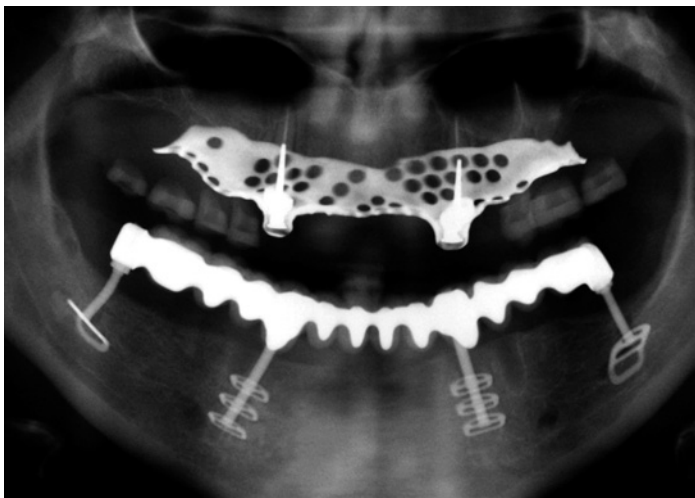


Fig. 3.10. While the anterior triple-disk BOI implants are rigid per se, the wide-spanning bridge and the strategic position of the implants creates an elastic bone-implant-restoration system where the jawbone can develop and move freely below the bridge. The fate of the bridge is not linked to that of the crestal bone

3.10 Conclusion

The design of BOI implants shows a clear structure. Appropriate designs are now available for every conceivable task. The following aspects of implant design are an integral part of the BOI treatment philosophy:

- Mucosal emergence points with small diameters prevent the penetration of pathogens and the development of peri-implantitis (for details see Chapter 8).
- Elastic design: The advantages of the elastic design are most noticeable if only a few BOI implants are placed in each jaw.
- Bicortical support: It is a good idea to place BOI implants such that they reach the cortical region on both sides of the jawbone.
- Selecting the longest possible threaded pin: Results in optimal access for oral hygiene and in autocleaning (see Chapter 8) and has a positive influence on elastic properties
- The choice of connecting abutments also has an influence on the elasticity of the structure (see Chapters 4 and 5)
- Sufficiently extensive vertical and horizontal osteotomies favour suppuration in the event of preoperative or intraoperative infection (see Chapters 8 and 23)

Insertion Tools and Implant Designs

4.1 Tools for External Thread Designs

To insert BOI implants a T-shaped osteotomy has to be cut into the bone. The instruments used for this are usually designed to cut either the vertical or the horizontal part. There are also instruments, however, that are designed to cut the vertical and horizontal parts simultaneously. Within limits these instruments can be replaced (e.g. with a tungsten carbide cutter) if required for intraoperative accessibility.



Fig. 4.1. A vertical cutter is used to prepare the channel for the threaded pin. At the same time this instrument prepares the ground for the lateral cutters to be used in the next step. The vertical cutter illustrated in this figure features FG tension at 1.6 mm and thus can be used with a turbine and high-speed contra-angle handpiece. The width of the working surface is also 1.6 mm. The cut width is thus smaller than the width of the threaded pin, which means that several cutting steps are required. Many users first apply a normal tungsten carbide cutter to expedite penetration of the hard cortical bone, which increases the lifespan of the vertical cutter. Note that the diameter of the vertical threaded pin is larger than 1.6 mm. This means that the slot has to be widened with the same instrument, which gives the operator a chance to slightly adjust the position of the slot and the vertical implant part



Fig. 4.2. Lateral cutter (LC), 12 mm in diameter

The lateral cutter is used to create the horizontal dimension of the osteotomy. Several lateral cutters with incremental diameters are used successively, starting with 7 mm. The largest cutter currently available has a diameter of 15 mm. In softer tissue and with a good turbine engine, cutters with larger diameter might be used right away, so that the vertical size of the horizontal slot does not become too large.

Twin cutters are used for double-disk implants. Their function is twofold: they define the disk-to-disk distance, and they ensure that both cuts are parallel. Twin cutters are available in two diameters: the 9-mm or 7-mm types define a disk-to-disk distance of 5 mm or 3 mm, respectively.

The use of lateral cutters without cutting features along the shaft has the advantage that the horizontal osteotomy can be created more speedily. This



Fig. 4.3. Twin (combi) cutter for two disks 7 mm in diameter that are 3 mm apart

presupposes, however, that the preceding vertical cut has been placed properly at right angles with the subsequent horizontal lateral cut. If that was not the case, a Combo cutter has to be used intermediately to create the required right angle between the vertical and the horizontal slot by «post-cutting» (adjusting) the vertical incision. Experienced implantologists usually have no problem placing both incisions correctly at right angles.

As a certain disadvantage of all FG instruments, the chucks may clot up with blood introduced during the procedure, as the surgeon will not always be able to ensure the absence of any blood on the surfaces to be inserted into the turbine during surgery. Therefore, some users prefer to work with instruments to be inserted into the blue contra-angle handpiece (1:1) because these handpieces work without chucks. One disadvantage of contra-angle handpieces, however, is that the shaft cannot be reduced in length; it is therefore necessary to keep cutters with different shaft lengths in stock.



Fig. 4.4. Combi cutter (KC), 10 mm in diameter, with cutting surfaces on both the disk and the shaft. These cutters are available with disk heights of 0.4 mm, 0.6 mm and 0.8 mm

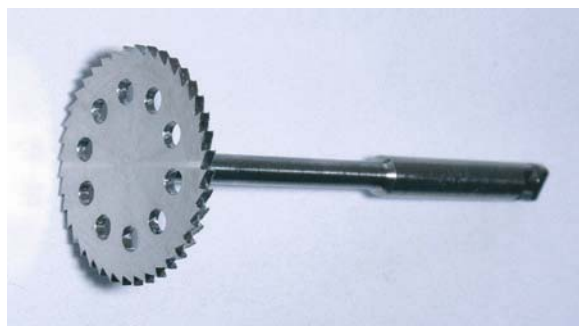


Fig. 4.5. Lateral cutter (12 mm in diameter) for contra-angle handpiece

4.1.1

External Implants (ED)

As a rule, single-unit implants are really what the name suggests, i.e. they are made of a single ingot of titanium, using a high-precision (and high-cost) manufacturing technique.

These implants evolved from rotationally symmetrical designs with one or several load-transmitting surfaces. The size of these implants is given as base surface area or radius in mm. The height of the threaded pin is given in G units (1G=1.5 mm) and is measured from the upper margin of the base disk to the beginning of the thread, thus including the shoulder below the thread.

Designs with a semicircular base can be used to protect the implant against rotation within the osteotomy slot, the round side being inserted into the depth of the bone while the flat side borders on the bone laterally (i.e. medially and distally) and towards the vestibular aspect. These designs offer very good primary stability.

In many cases, the cortical bone structures in the maxilla and mandible are located 12–14 mm apart. As rotationally symmetrical designs cannot not be readily inserted in this situation, it is recommended to use lengthy BOI designs. The most appropriate design for this purpose is the EDAS implant (available as 9×12 mm, 9×14 mm, or 10×14 mm), EDADS implants (12/17 mm), or EDAAS implants (10×20 mm).



Fig. 4.6a,b. ED 9G8 und ED 7G8. These two implant types are extremely popular, since the specific relationship between the disk diameter and the shaft length allows their application in a great number of clinical situations. These designs are also extremely reliable



Fig. 4.7. Double-disk implants 9/7 G5. The G5, G7 and G8 versions of these double-disk implants (9 or 10 mm diameter at the base disk) are commonly used to replace canines in both jaws

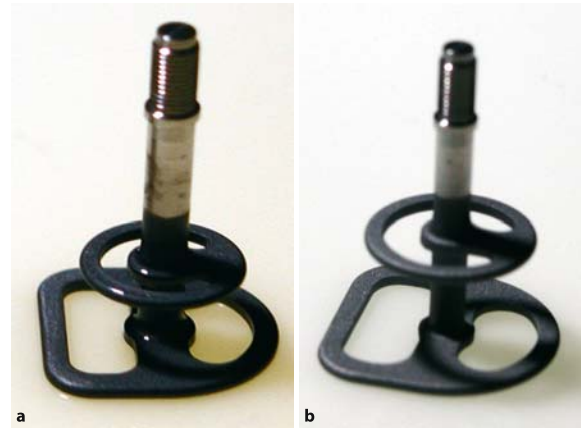


Fig. 4.9a,b. EDDS implants (right) are well suited for insertion into stable bone structures. If the vertical bone volume is greater, it is recommended to use EXDDS implants (left), as the greater distance between the load-transmitting surfaces (5 mm) will prevent BMUs from interfering with each other during bone repair processes (see Chapter 23)



Fig. 4.8.a EDS implants feature a basal plate that is basically circular but with a longer radius towards the angled ends. The implant is thus protected against rotation in the bone cavity. Furthermore, its lateral segments stabilize the implant against removing forces by increasing the friction. EDS 9G6 are used most commonly in the area of the second molars in the mandible. **b** A design with two additional edges offers much greater primary stability (and an intrabony anti-rotation feature) than a circular design with the same base diameter. Designs with edges and flat base-plates are called “S-Type implants”.

EDAAS implants feature one rounded and one flat side, but they are also available with two rounded sides. Maximum dimensions are 20 mm in width and 10 mm in height. Because the threaded pin invariably has to be centrally located during implant manufacture, titanium ingots with a diameter of over 30 mm would be required. In order to economize on the amount of titanium used in the manufacturing process, the threaded pin was shifted 2 mm from the centre of the circle in a medial direction, i.e. towards the centre of the implant. Available lengths range from G5 to G9.

The tendency of users to place fewer and fewer implants in each jaw is also reflected in the development of implant designs. Today's Diskos implants, for instance, are characterized by a disk height of 0.6–0.8 mm. The materials used for this design include pure titanium (grade 1 or 2) and Ti15Mo. For optimal fracture resistance, the radius in the transitional zone between the threaded pin and the web bar has been reinforced, and the web bar itself is also thicker as well. While these features allow for greater loading, it is nevertheless important to keep in mind that due to the elasticity of the bony implant beds, close osseoadaptation of all implant surfaces cannot be possibly attained in the presence of a high degree of mineralization. Thicker implants



Fig. 4.10. EDA implant (7×16 mm) with centrally located threaded pin

are less elastic than thinner implants made of the same material. This phenomenon becomes relevant mainly with implants transversing bone structures that are out of sync in terms of dislocation. Thicker implants are more likely to be selected when strategic implant positioning is planned.

4.1.2

Abutments and Components for External-Thread Designs

The three abutment types in Fig. 4.16 are perfectly serviceable for most applications.

The total height of these implant types is 6.5 mm for TSD4 and 10.5 mm for TDS5 and TSD99. The TSD99 abutments have a more internal/superior position of the internal threading as distinguishing feature, allowing longer implant shafts to be adjusted in a mucosal direction. The advantage of TSD99 abutments is that they offer a very long surface for cementing even on ED implants whose thread is located in a very high position. Frequently, abutments on long threaded pins have to be reduced down to the thread, which would bring the length available for cementing down to the thread length of roughly 3–5 mm. Deficits of this type can be easily eliminated by using TSD99 abutments, which will increase the available surface for cementation by another 4 mm in mucosal direction. Nevertheless, care must be taken that no direct contact to the mucosa is established, since the apron-style coverage tends to favour retention of food remnants. It is frequently a good idea to decide on using longer threaded pins during the procedure and compensate for the increased length by using TSD99 abutments for the prosthetic superstructure. In situations where the threaded pin is located in a sloped mucosal area, the TSD99 abutment and the spaces in the superstructure designed to hold them can be reduced obliquely.

The same abutment types are also available in white Delrin. These designs are more elastic, a feature is preferred by many BOI users. DA abutments can be bonded with glass-ionomer cement to obtain a semi-permanent connection that is stable yet allows de-bonding in a relatively simple manner if the need arises. Combined with cements like Panavia, they may be used for definitive cementation. Delrin abutments are unsuited if the BOI is to be flexed for angulation because they are liable to break in this specific situation. Instead, it is better to use titanium



Fig. 4.11.a EDAS 9/12 G5. This implant design is predominantly used in distal jaw segments. EDAS implants are also available with three web bars radiating from the threaded pin. **b** EDAS implants are also available with three web bars



Fig. 4.12. EDAS 9/14 G7. This implant type can be used as either a 9×10 mm or a 9×14 mm design by removing one or the other of the web bars. It is also possible to install the base surface of 9×10 mm enossally and fold the second bar area on the vestibular or palatal aspect as needed



Fig. 4.13. This type of BOI implant features only one contact site on either cortical bone structure; therefore, only these two areas have to be synchronized (EDAA 10–20 G8). These types are mainly used in the area of the maxillary sinus. The bevel visible on the right side of the basal plate will centre the implant during trans-sinus insertion into the palatal slot. The implant can be placed with the projecting side either towards the right or towards the left. Note that the amount of load transmitted to the cortical bone is inversely proportional to the size of the basal plate on each side of the threaded pin. Since there are two penetration locations of the cortical bone on the square side, a o-area inside the bone may sometimes develop around one of those penetration areas (see Chapter 9 for details)

abutments or the TAP-D tool (screwed onto the thread) for this type of manipulation (see Video 7).

If the transitional zones to the implant come to lie in a submucosal position anyway, abutments with

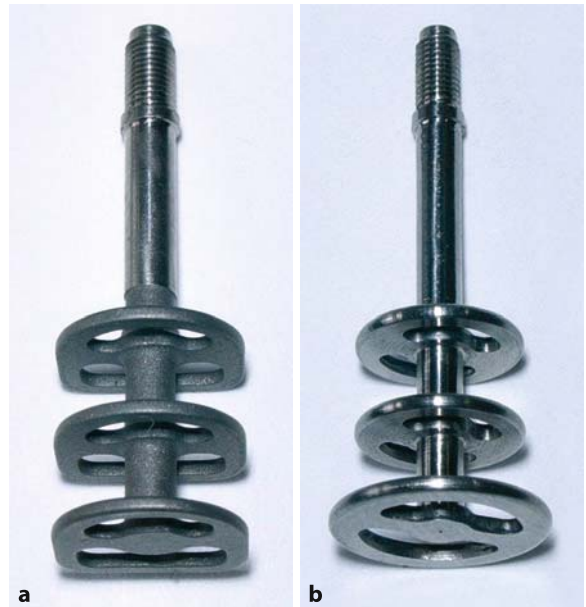


Fig. 4.14a,b. Triple-disk BOI implants are available with a diameter of 7 mm with and without bevelling (external thread version). Triple-disk BOI designs featuring a larger disk at the bottom – thus adapting better to common anatomical situations – are also available

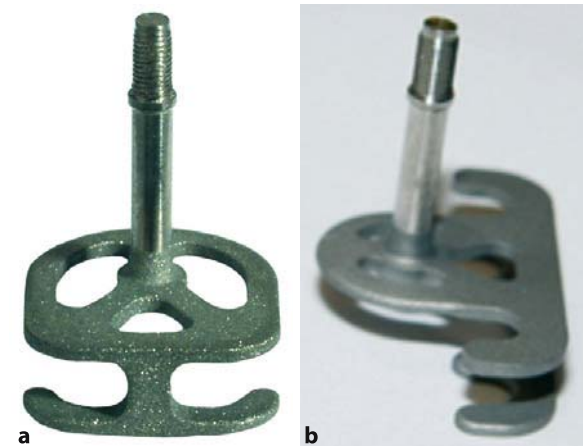


Fig. 4.15a,b. This implant design with a second vestibular semi-disk is predominantly used below the maxillary sinus. The double-disk segment is inserted vestibularly; only one disk transverses the sinus. The basal semi-disk may be angulated (see Video 9)

an apically polished neck area of 4 mm length can be used.

Abutments made of Delrin can also be used if greater elasticity of the implant-restoration system is desired. The DA5 and DA99 designs feature the same external measurements as their metallic counterparts. Thus the user can wait until the cementation step before deciding on which implant type to use. Delrin



Fig. 4.16. Standard abutment designs TSD4, TSD5 and TSD9



Fig. 4.17. Abutment designs DA99, DA5 and DA4. Note that these abutment are not visible on X-rays. For this reason and also because they are quite elastic, one can get the wrong impression that the bridge is not connected by an abutment at all



Fig. 4.18. Abutment designs TSD44 and TSD55 (with elongated polished necks) compared to the shorter TSD4 and TSD5 designs

abutments will allow for greater mobility in the transitional zone between the threaded pin and the abutment.

While the surface area of the implant base (ignoring any rounded edges) is given in millimetres (e.g. 10×14 mm for EDAS 10/14 G6), the length of the threaded pin is classified in grades (1G=1.5 mm). This G categorization is used across the world for

all BOI systems. Pin lengths of G5–G7 are most commonly used. Shorter pin lengths are rarely used, while greater lengths (up to G11) are becoming increasingly popular. Threaded pins in the G9–G11 range have only been available in the past few years; hence it will take another while before their therapeutic usefulness and scope of applications are going to be widely recognized.

BOI implants can be installed and immediately loaded right after extraction in the same session, as the cortical ridge structure is usually well preserved following extraction. It is recommended to insert the threaded pin through a lateral pathway into the available bone whenever possible. This approach can be routinely applied in the maxilla, for instance, where the interradicular bone volume is frequently adequate after extraction of the first and/or second molar. Any inflammatory processes that may still be present in the bone need to be carefully eliminated. Special care must be taken that any residual inflammations are allowed to drain off around the load-transmitting disks. Thus the position of the disks, and hence the insertion path, must be carefully planned to avoid any repositioning of the – often deeper – alveolae.

4.1.3

Tools for External-Thread Implants

See Fig. 4.20, 4.24a, 4.31a–f.

4.1.4

Compatible Crestal Implant Types: KOS System and S Implants

Compression screws of the KOS type can be conveniently combined with BOI implants thanks to their identical configuration. This is one of the reasons why many implantologist like to use both implant types side by side for bar attachments in the mandible (see also Chapter 19). Combination of KOS screws and BOI implants is also useful in knife-edged maxillary ridges.

4.1.5

Semi-permanent Bonding on ED Implants

The development of semi-permanent bonding options has been characterized by different approaches:

- Cements based on methacrylate compounds (e.g. Cerafix Genta (CeraVer GmbH, Frankfurt, Germany) have been used that allow for debonding by thermal action (application of heat). The heat can be generated by applying rotating

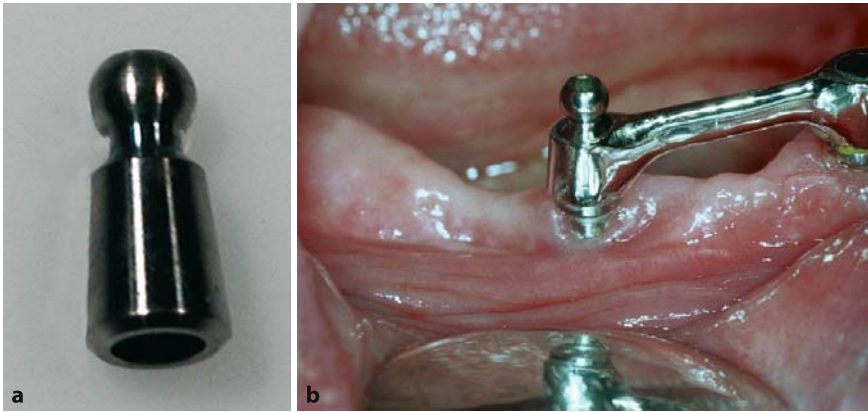


Fig. 4.19a,b. The TSD-SB abutment design is used together with an NC nylon cap to establish a reversible connection of the prosthetic structure and, at the same time, cementation (e.g. of a stabilizing bar attachment) in the area of the conical abutment segments. The clinical application is illustrated in b. The ball retainer integrated in this type of abutment does not have to be soldered to cast onto the bar attachment. b Since TSD SB abutments have the ball retainer as integral components, the bar attachment is fabricated with only one cast-on ring that is slipped over the ball retainer and secured by adhesive bonding or cementation



Fig. 4.20. Insertion aid IT KOS is used to screw and tighten the abutment over the external implant thread. The head of the tool is compatible with the RAT2 ratchet and other tools (e.g. with the ITI System)



Fig. 4.21. Transfer copings allow impressions to be made even in situations where an abutment area of adequate length is not accessible for the impression material due to postoperative swelling or deep placement of the implant.

instruments (notably tungsten carbide cutters) to the framework or the abutment area.

- Circlip systems (e.g. SR5; material: Ti Grade 5). These systems must be equipped with precision grooves (e.g. SA5; material: CoCrMo) in the framework and with special abutments featuring grooves as well. The degree of precision required in the dental laboratory is substantially higher than with cemented units. If the required degree of precision is out of reach due to the extent of muscular jaw flexion, passive cementation must be performed (particularly in the mandible). The restoration can be removed by destroying the circlips and replaced by substituting new circlips. (Temporary) cements or silicones are used additionally to close any gaps between the abutment and the groove, thus minimizing bad smells and bacterial retention.
- Double-threaded screws facilitate the insertion of prosthetic structures mainly in situations where the abutments show very different axial inclinations. In the presence of mandibular ridge resorption, for instance, permanent cement can be used for the anterior abutments, while the distal abutments are connected with double-threaded screws. This solution certainly has the disadvantage that the space requirements for the various components are greater. Double-threaded screws will also allow temporary bridges to be inserted in such a way that they can be conveniently removed. The external threads of the double-threaded abutments are made from CrCoMo, so that these parts can be connected directly to the bridge by plasma or laser welding.
- Since the vertical dimension cannot be easily maintained when double-threaded screws are

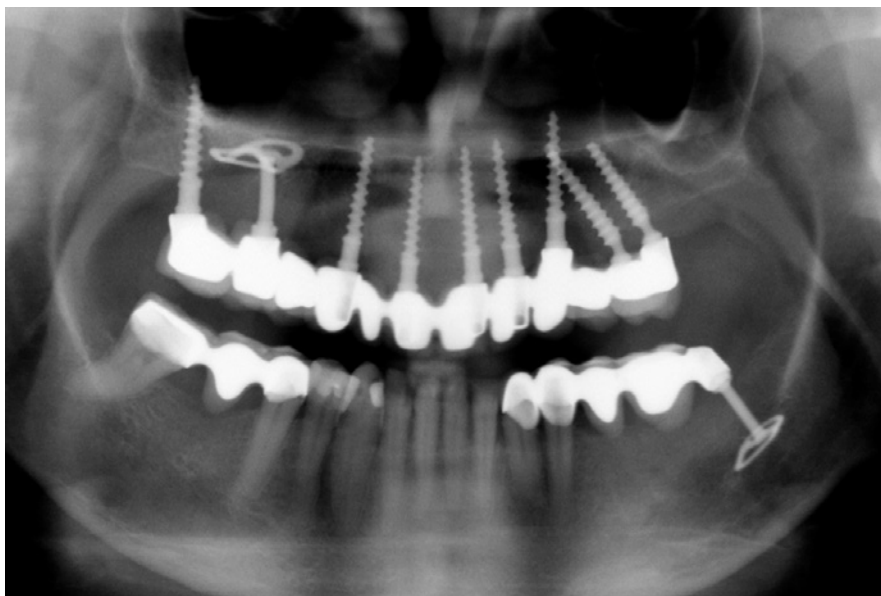


Fig. 4.22. Combination of KOS and BOI implants utilizing the existing native bone structure. For the KOS screws, the maxillary ridge had to be horizontally expanded. Thanks to the large number of implants, a temporary bridge could nevertheless be inserted and immediately loaded

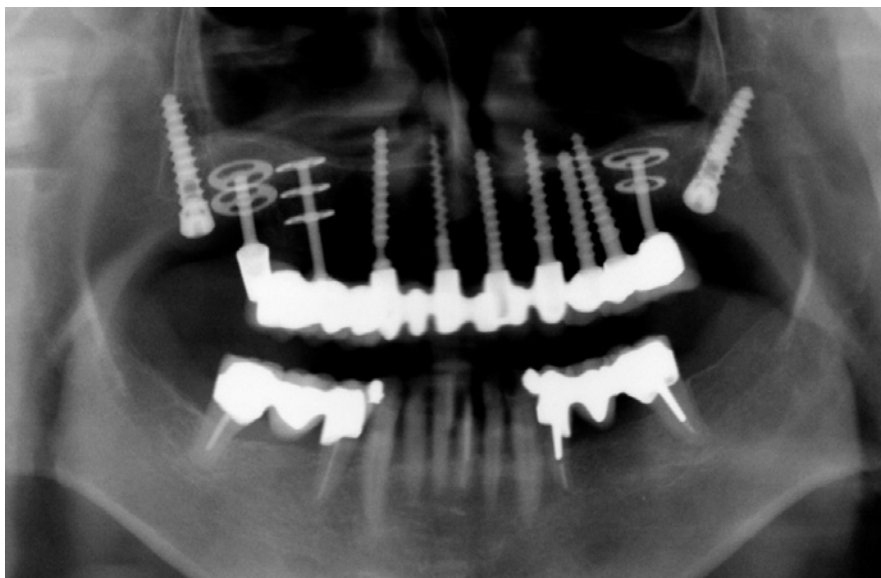


Fig. 4.23. Tubero-ptyergoid screws are normally not included in the temporary restoration. Sometimes they can even be excluded from the definitive restoration, provided that all other implants are successfully osseointegrated and the anterior implants are adequately stabilized. See Chapter 16 for details regarding this concept of tuberoptyergoid screws

used, the screw has to be turned to the thread of the implant before the cementation of other implants abutments is performed. Otherwise, if cementation is performed in the presence of anterior support only, the distal bridge segments may suddenly turn out to be in an infra-occlusal position following cementation. If double-threaded screws are used throughout, the height can be checked, and any subsequent adjustments performed, more easily. Unfortunately, the use of double-threaded screws in the anterior segment is usually not often an option, since they require much space and a rather palatal location of the

threaded pin. Both may give rise to phonetic problems.

- As indicated above, bridges that will have to be removed in due course can be cemented in a semi-permanent manner by combining glass-ionomer cements or phosphate cement with Delrin abutments (DA4, DA5, DA99). This approach can also be adopted in situations where roots that cannot be preserved in the long term can still be incorporated for initial stability or bone preservation on a temporary basis. A case like this is illustrated in Fig. 4.25a–d.

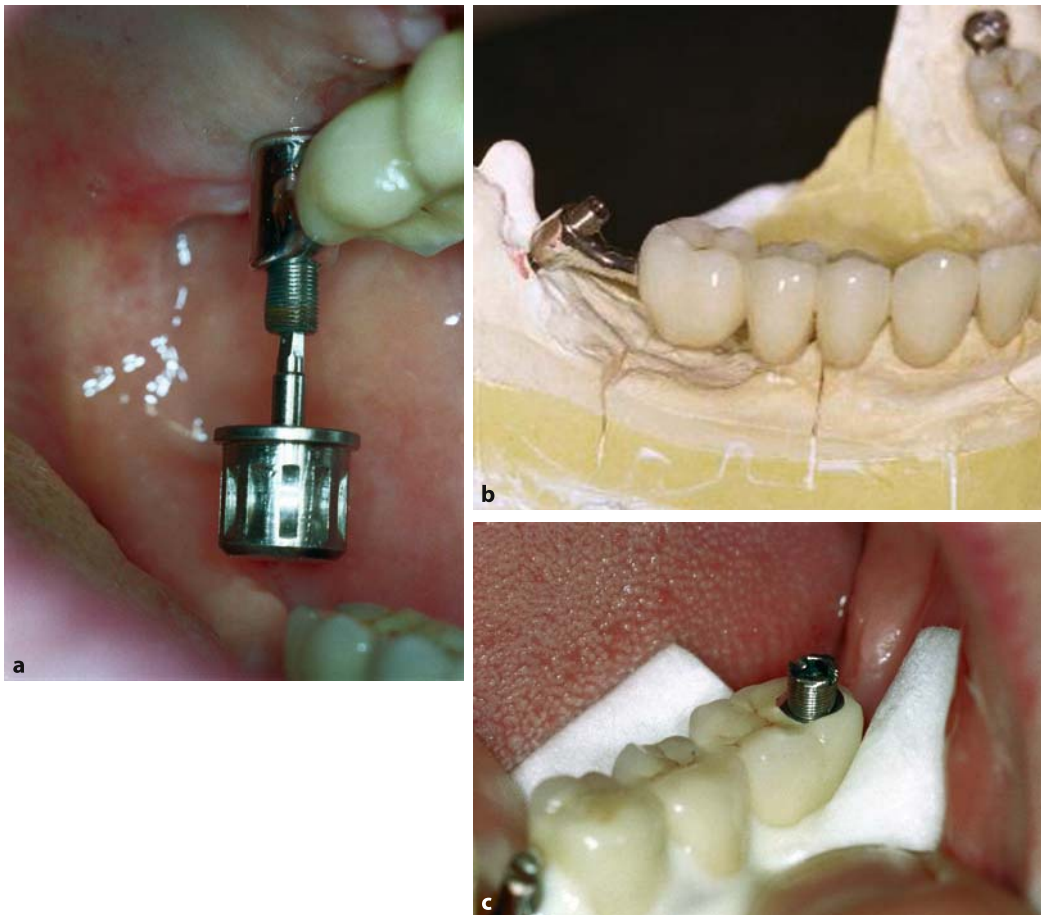


Fig. 4.24. **a** Double-threaded screw for an external BOI implant. Screwing is performed with an HTS 1.25 hexed instrument, which comes in two different lengths (the figure shows the short version). **b** In the mandible, double-threaded screws are a good choice in situations where the insertion path differs considerably between the distal implants and the anterior abutments (teeth or implants) while the implants cannot be flexed due to the reduced vertical dimension. The important part during the cementation step is that the implant thread is placed centrally into the internal thread of the prosthetic superstructure. The double-threaded screw can be placed simultaneously with the cementation step or later. **c** Double-threaded screws can also be positioned on occlusal surfaces. In this case, the restoration was cemented at 34 and screwed to the BOI implant at 36

4.2 Internal Designs with an External Hexagon (ID System)

The ID series according to Scortecchi was developed in combination with «Structure» screw implants in the very early phase of screw implant designs.

They feature an internal thread (M 1.4), which is combined with an external hexagon surrounded by a ring-shaped enclosure. This design is only compatible with the structural screw implant system. The big advantage of this type of design is that the external octagon does not protrude from the restoration surface of the implant. This allows the insertion of restorations even where the implants themselves are not parallel. This feature also makes

insertion easier where tuberopterygoid screws are involved.

4.3 Internal BOI Designs with an External Octagon

4.3.1 Internal-Thread Designs (IDO System)

IDO implants have a much more rigid design than ED implants. The threaded pins have a diameter of 2.3 mm (ED 1.9 mm), and the prosthetic structure is typically mounted to the implants via a screwed connection. The surgeon is thus faced with the

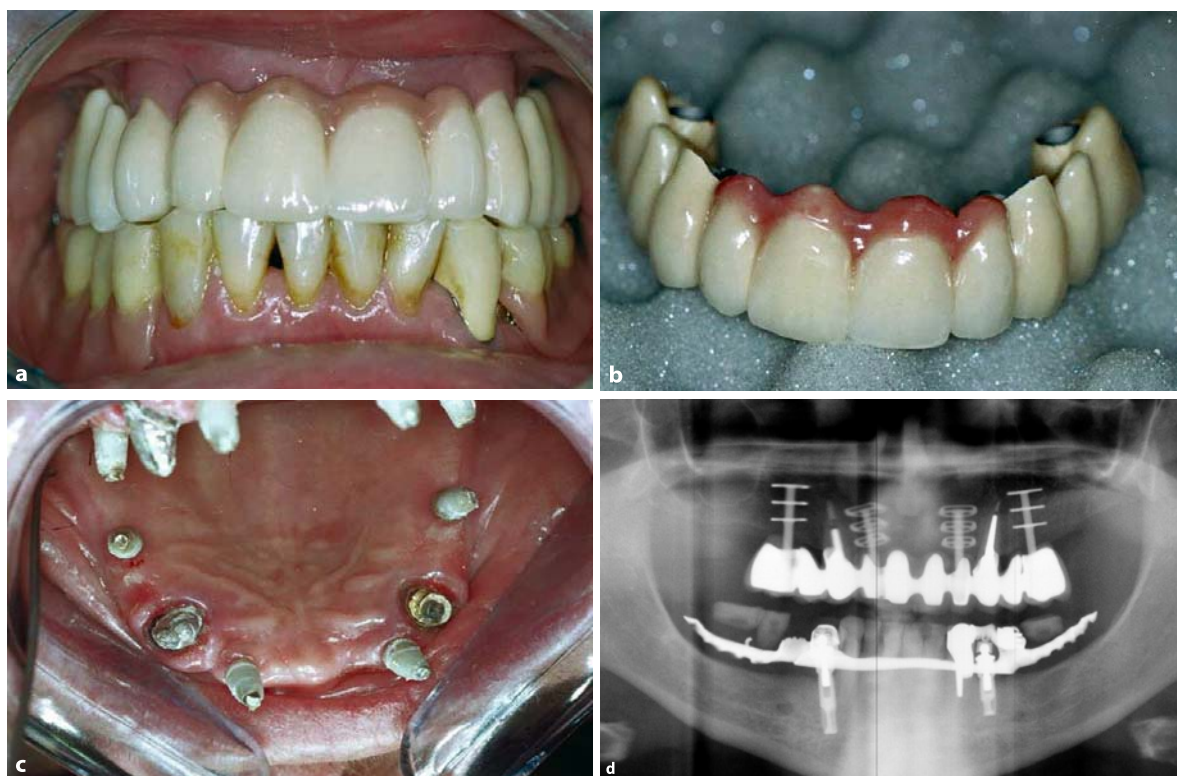


Fig. 4.25. **a** The basal segment of this maxillary bridge was reinforced with pink porcelain due to volume problems following the loss of incisors. The residual canines will maintain the width and anterodistal dimension of the ridge. Therefore, extraction of canines should be delayed as long as possible, which can only be obtained through semi-permanent cementation. **b** Frontal view of bridge before semi-permanent cementation. **c** The two canines are not needed to retain the bridge, which is stabilized perfectly well by the inserted triple BOI implants. Still, the canines are able to preserve the available bone width for a certain period of time, which will significantly improve the situation in terms of volume and aesthetics. For semi-permanent cementation, pointed DA abutments are combined with glass-ionomer cement. Note that semi-definitive cementations on teeth using Temp Bond are only possible for a limited period of time, since teeth tend to decay underneath these cements. **d** Panoramic radiograph of the same case

additional challenge to position the implants in such a way that the screws are not located in a facial position. IDO implants do, however, offer the definite advantage of allowing the prosthetic structure to be removed at any time. Since the distance between the disk and the cup-shaped head varies depending on the G value, a dedicated initial cutter needs to be used for each G value.

4.4 Tools for Surgery

It is recommended to keep all surgical instruments handy in a well-structured layout. The compartment on the right can be used for implants that were unpacked but not used on a previous occasion.

Sometimes it is necessary to shorten ED implants – for example because the shorter length needed is not in stock during surgery, but also it may also turn out to be necessary later, at the beginning of

the prosthetic phase of treatment, as the gingiva may have contracted by unexpected extent, leaving a long exposed surface of the threaded pin visible. The TAP-D instrument is used to create a new thread on ED-implants after the original thread has been lost or cut off.

4.5 Internal Versus External Thread Designs

The advantage of ID implants is that the dental technician has no problems with the vertical dimension, as the screw connection extends deep into the internal thread, while the space requirement above the mucosa is only 2–3 mm. Despite this relationship, the screw connections have to be placed at the gingival level to permit access for cleaning and to avoid pocket formation. The large diameter of the cup penetrating the mucosa allows microorganisms to advance deeper. For this reason, ID and IDO

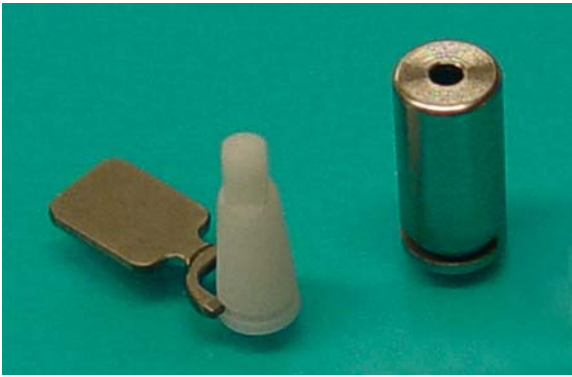


Fig. 4.26. Another option of connecting superstructures in a semi-permanent manner is by the use of circlips. The circlip shown on the left is inserted through the slot shown on the right until it engages the groove of the abutment. Then the handle is broken off the ring. For removal at a later time, the ring has to be destroyed



Fig. 4.27. IDD 9 G4. The connection parts (internal thread and hexagon) are clearly visible

implants do not feature surface-enlarged cups or threaded pins. Also, screwed structures can be removed more easily than cemented structures.

On the other hand, ID implants cannot be used for elastic implant-restoration systems due to their wide cups and more rigid designs. Since the prosthetic screws are thinner than the threads of ED systems, they are more susceptible to breakage and loosening.

The most difficult part of the insertion procedure for ID implants is to place the cup at its correct level. While ED implants are always placed in multiples in a lingual or palatal direction to create space for aesthetic considerations, the ID implants must be associated with an «emergence profile», i.e. the new «tooth» is developed from inside the gingiva at the position of the cup. Restoring aesthetics with ID implants is a more complex task, particularly when the gingival levels are very different and in the presence of vestibular collapse following periodontal disease. Close attention must be paid to this aspect during the surgical procedure. It should be remembered that ID and IDO systems cannot be subsequently reduced in length, which means greater care must be exercised in stock-keeping. On the other hand, prosthetic structures on ID and IDO implants may be unscrewed, which facilitates any follow-up treatment aimed at replacing implants or repairing the prosthetic structure. ED implants – particularly the more recent designs featuring smooth shafts – virtually never result in crater-style collapse of the marginal bone structure, and they are always well accessible to brushing and flossing by the patient even if the porcelain restoration is characterized by vestibular overcontouring. They also offer favourable conditions for self-cleaning.

This is an essential reason why prosthetic units are usually connected to ED implants by way of

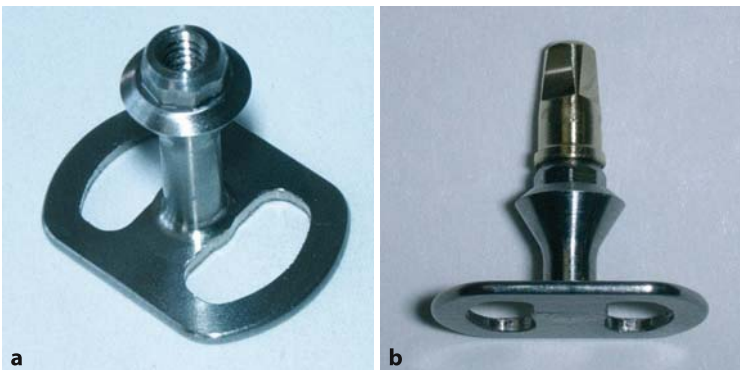


Fig. 4.28.a IDO 9/12 G5. The octagonal head is compatible both with S-implants and ITI-implants. Due to the centric position of the threaded pin, the horizontal cut must be carried further than the threaded pin itself would require, which can be achieved by using an LC9- or LC10-type cutter. **b** For IDO-implants cementing abutments are available. They are screwed into the internal thread of the octagonal head. The crown must be cemented over the abutment and reach the outer ring, which features a diameter of 4.8 mm



Fig. 4.29. LC7 cutter for contra-angle handpiece used for cutting the cup at a G3 distance. For each G-length a separate cutting instrument is necessary



Fig. 4.30. Fully equipped surgical tray for instruments for FG tension

cementing. Periodic removal of the prosthetic superstructure, as frequently recommended with crestal systems and ID implants, becomes necessary less frequently, as the thin emergence points of the abutments tend to have favourably good self-cleaning properties.

As mentioned, the prosthetic screw for ID implants consists of pure gold and is designed to undergo plastic deformation during screwing, thus maximizing the surface area of the screw connection to reinforce retention of the prosthetic superstructure. Fine-gold screws also show higher fracture resistance because they are soft (see for further details www.diskimplant.com).



Fig. 4.31.a Tap featuring a head that is compatible with a RAT2 ratchet wrench. The tap can be used for: (1) safe flexing of the threaded pin during the procedure; (2) creating a new or longer thread before or after implantation; (3) removing any calculus, concretions or other debris from external threads; (4) repairing the external thread after inadvertently inserting the abutment at an angle. **b–f** If the implant looks excessively long during placement (and if no other implant is available), it can be reduced and fitted with a new thread. For this purpose, the base of the thread has to be removed as well. The softer titanium alloy of the threaded pin will be somewhat compressed by the harder material of the abutment. Abutments (on re-tapped threads) should not be removed once they have been tightened, since firmly tightened abutments are likely to have a strain-hardened connection interface. Ti15Mo-implants cannot be given a new thread in this way because the implant material is too strong



Equipment and Surgical Techniques

5.1

Plans and Outcomes and the Coexistence Between Living and Dead Objects

People tend to think it is rather logical that installing fixed teeth is an advantage. But often enough it almost seems that the jaw that is receiving the requisite implants begs to differ. It is any implantologist's desire for the jawbone to enter into a state of peaceful coexistence with the implanted object. In our opinion, this works best if the basic functions of the bone are not impaired. These basic functions include the motor function that is required for the survival of any bone and the unimpeded flow of nutrients, gases, and waste products.

5.2

General Considerations

Before the implant procedure begins, pain-relieving measures must be taken. The surgical site is disinfected with chlorhexidine digluconate or Betadine. Furthermore, the dentist may choose to oil the corners of the mouth, with or without previous application of eosin.

The implant can only be placed after a paracrestal flap has been reflected longitudinally to the jaw. A mucoperiosteal flap is liberally dislodged and well secured to avoid any contact with rotating instruments. Based on our clinical experience, there is a distinct relationship between the size of the full thickness flap and the level of postoperative pain. The level and duration of postoperative pain can be reduced, however, by keeping the procedure relatively short and liberally dislodging mucoperiosteal tissue for flap reflection. Experienced surgeons will usually take no longer than around 60 min for a complete implant procedure designed to support a full-arch restoration. Note that the flap must be reflected far enough so that the incision cannot interfere with the disk area of the planned BOI implant.

If any teeth are to be extracted in the same procedure, the incision is designed such that a coronal advancement flap can be formed to be drawn over the alveolus. The adjacent teeth are not

circumcised in this situation. This is particularly important if any residual teeth located next to the implant site are to be left in place.

Our strategy in periodontally involved areas is to circumcise any granulation areas and remove them along with the teeth. The best way to deal with multi-rooted teeth, unless they are overly mobile, is to separate them at the root level to preserve a maximum amount of bone. On the other hand, any bone structures that will presumably be lost to resorption should be removed right away, so that there is no way for any portions of the implant disk to be inadvertently included in those structures. Since macrotrajectory-driven bone resorption is inevitable, any disk areas that come to be located inside such bone structures are certain to lose their enossal support. In order to correctly position the implant in all three planes, the surgeon must remain aware of the «big» picture during the osteotomy procedure rather than concentrating solely on the instrument. Novices in particular tend to focus too much on the immediate bone structure, thereby losing sight of the instrument axis, the relative cutting depth and the endpoint of cutting. The implant axis is normally selected without regard to the inclination of the vestibular bone structure. The goal is to secure bicortical anchorage of the disk in a position that is consistent with the available bone structure.

As an additional requirement in IDO/IDOT implants, the screw access holes must not come to be located in an aesthetically relevant position. These designs are thus much more difficult to use in the aesthetic zone, particularly since their threaded pins do not allow bending. The same applies to ED implants made of Ti15Mo. The threaded pins of these designs cannot be bent in the intraoral environment either.

Thanks to their smooth surface design, the shafts of BOI implants are perfectly suited to reside in free gingiva. (However, the strategy of flap preparation should, whenever possible, lead to a result where attached mucosa is placed around the threaded pin.)

The implant bed is created through a lateral access using vertical cutters, horizontal cutters and



Fig. 5.1. **a** When the horticulturist determined the design of this fence and the relative positions of the fence and the trees, he can hardly have been aware of the enormous strength and the possible extent of future growth. How could he otherwise place such – prospectively – massive trees right next to a delicate, skeletonized fence? However, both these units, the tree and the fence, were able to agree on a mutually acceptable level of peaceful coexistence and in this manner weather the decades. **b** Over the years, then, the tree that was condemned to grow and the fence that was condemned to withstand must have come to some kind of arrangement. Quite probably, it is now more the tree that holds the fence together than the fence's own screws. A comparable result of peaceful spatial coexistence between living and dead matter is the objective of our enossal implantological work – whether we use crestal or basal implants. Within the contact areas, located inside the tree, the fence determines the positions and orientations of the macrotrajectories. That the fence (even if it had been made from titanium with the most miraculous surface) constitutes an additional stimulus for the tree to grow is something we would not suspect. But close observation of the different parts of the trunk emerging more fervently or more weakly lead one to assume that the 0–1 rule does hold for trees as well (see Chapter 9 for details of this aspect). **c** This tree was equally capable of bearing the burden of the years and the proximity of the fence, this time without any intimate connection between the two being necessary. A comparable result of peaceful spatial coexistence between living and dead matter can be the objective of our implantological work with subperiosteal implants or bent over vestibular BOI struts. **d** Peaceful coexistence must have existed here, too, at some point in the past. However, circumstances that probably were unrelated to the fact of coexistence itself have only afforded the living matter a shorter time span to survive

combination cutters. The first vertical bone cut can be performed with a tungsten carbide cutter to avoid unnecessary wear of the vertical cutter.

The preparation is usually performed with a turbine under profuse irrigation. Turbines offer the advantage of a low torque, i.e. they will even stop rotating when the surgeon uses excessive force. This precaution will avoid both heat-related injuries to the

bone and premature wear of the cutting instruments. Helpful tools also include high-speed contra-angle handpieces and the ELCO system with on-board torque control recently introduced by W&H. The latter system is optimally used in conjunction with a contra-angle handpiece 1:2.7 at 20,000 or 40,000 rpm with the torque adjusted to 30%. High-speed contra-angle handpieces mounted to conventional

dental units do not always offer torque adjustment. The cutters may sometimes bend in the hands of inexperienced surgeons, as even minor rotational imbalances from the bearing if the instrument will immediately deform the cutter when working at high torque. After all, the instrument reaches high speeds almost instantly. The speed of rotation as such, no matter how high it is, cannot inflict anywhere near the damage done by an excessive torque.

Once the vertical and lateral bone cuts have been created, the implant is inserted through a lateral access using carefully dosed hammer-style strokes. As the structural height in the basal plate area may vary depending on the exact design, it may be necessary to elongate the vertical cuts further to match the desired implant design. Overly forceful strokes that mainly hit the threaded pin should be avoided as they may induce plastic deformation along the pin and/or the web bars. If any parts of the implant are subjected to plastic deformation, these parts will be harder than the remaining non-deformed parts.

In this situation, areas of peak stress concentrations will develop right next to the deformation, carrying an increased risk of fracture if subjected to powerful cyclic loads. Not only may the vertical osteotomy be too narrow, but implant insertion may also be impeded if the horizontal osteotomy is too small. The height of the horizontal osteotomy is mainly selected in accordance with the thickness of the implant disk. Bone quality is, however, also a factor. In the posterior segment of the maxilla, it may be a good idea to create an undersized implant bed: some users like to insert 10-mm implants after using a 9-mm cutter for the preparation. This approach offers good primary stability of the implant. Note that the horizontal osteotomy must be advanced deep enough so bicortical anchorage is achieved.

In the mandible it may be necessary to take the reverse approach, namely to insert a 9-mm implant after preparing a 10-mm implant bed. Sometimes this is the only way to insert the implant without inflicting damage. As the central portion of the web bars is vertically reinforced compared to the peripheral portion at the ring, an adequate clamping effect is present between web bar and ring.

Sometimes the cutter may suddenly become jammed inside the bone and resist being removed. Such jamming is particularly common in the process of expanding horizontal slots in the distal mandible to 9 mm and is caused by plastic deformation of the jaw itself, which is subjected to strong flexion during mouth opening. Jaw structures will yield more readily to flexural forces while horizontal cutters are being used because they have been weakened by the previously established vertical cut already. The resultant plastic deformation stems from

microcracks. Bone tissue permits crack formation while resisting crack propagation. Composites share this property as well, whereas glass behaves the other way round by permitting a certain degree of flexion but breaking along its entire surface once the point of no return has been reached, thus lacking the structural ability to prevent downright failure.

The extent to which the mandible is plastically deformed correlates with the degree to which the alveolar crest has been separated and the cut extended in a medial direction. The reader is referred to Chapter 11.1 for a detailed discussion of the biomechanical implications of weakened bone structures in the distal mandible for the vertical dimension. Some users prefer to insert BOI implants through a lingual access (particularly in the left mandible) if that area is well accessible and the cortical bone volume has been found to be greater on the vestibular aspect.

Slot gauges can be used to ascertain that the implant will smoothly glide into the slot. These aids are made of a titanium alloy featuring a polished surface. They can be cleaned and reused. Experienced users will not normally use a slot gauge, because there is no reason why the implant should not fit into the slot if the cutter could be advanced smoothly and the insertion procedure is not delayed. However the use of a slot gauge may be appropriate if the osteotomy was performed in a seriously resorbed area of the maxilla or mandible to avoid chipping of the fragile bone cover by having to use excessive force during the insertion procedure.

Whatever the case may be, the dentist has to make sure that the osteotomy extends into both cortical bone structures and that the implant can be smoothly advanced through the slot.

Non-resorbable grafting materials for the bone cuts are contra-indicated in the mandible because there is a risk that the material may migrate and give rise to chronic irritation of the mental nerve. Anyway, the stress-related regenerative capacity of this bone is so good that the slots will close spontaneously by native bone growth. Another convenient option is to introduce blood-derived autologous membranes with a calcium phosphate or calcium sulphate additive into the slots (Dohan et al. 2003; Blom et al. 1998). The osteotomy pathways may be obstructed by calcium sulphate or (tri-) calcium phosphate powder as substrate donors. Our impression has been that calcium sulphate is a highly effective mediator of soft tissue closure. Furthermore, it appears to reduce postoperative pain. These findings are subjective and remain to be confirmed in formal studies.

In the maxilla, any major bone defects may be filled with grafting materials (TCP, HA, autografts or allografts/xenografts) or covered with PRF. The

important part is that the grafting material can be safely closed, so that it cannot become infected. Such sealing cannot possibly be achieved if the augmentation has been performed along the threaded pin. The option of performing augmentation procedures at sites of extraction that used to harbour periodontally compromised teeth or, for that matter, putrid processes should be considered with some scepticism because there is a high risk that the grafting material may become infected. If grafting is performed in these cases, the suppuration outside of the bone must be considered and a path for suppuration must be left. The implantation procedure as such is, of course, not contra-indicated in these situations nor is this preoperative situation an absolute contraindication for grafting in combination with the placement of BOI implants.

The thickness of the bone cuts depends on the implant design. EDXS-type single-disk implants feature a peripheral disk height of 0.8 mm, thus requiring the use of thicker cutters. The following cutters are available:

	H 0.4 mm	H 0.6 mm	H 0.8 mm
ø 9 mm	×	×	×
ø 10 mm	×	×	×
ø 12 mm	×	×	
ø 15 mm	×		

While it may be possible to use an „undersized“ cutter in the maxilla to improve primary stability, a cutter of roughly the same dimensions as the implant is required in the mandible. Furthermore, it is recommended to use a 10-mm cutter for EDADS implants with a basal surface area of 9×14 mm to be inserted in the distal segment of the mandible. After all, the implantologist will never succeed in cutting a perfectly straight slot into the bone. Therefore, the implant cannot be advanced without jamming unless the slot is slightly wider in the first place (i.e. 10 mm instead of 9 mm).

5.3 Irrigation

Irrigation is usually necessary to protect the bone against overheating. The fact that such cooling must be provided during drilling procedures is not really open to debate. Albrektsson (1985) and Eriksson et al. (1982) demonstrated that a temperature of 47°C maintained over 1 min will give rise to significantly reduced bone growth in the vicinity of *roughened* implant surfaces. A temperature of 44°C maintained for up to 1 min, by contrast, does not induce demonstrable reductions in bone formation. Much more controversial is the issue whether it is possible to ensure adequate cooling deep inside the osteotomy cavity, especially when high-speed rotating instruments are used. While this question has been addressed in a number of excellent studies, the clinical relevance of these findings needs to be reappraised against the background of modern implant technology.

Scortecchi and Doms (1987) demonstrated that heat does not accumulate in a significant way due to the water-air exchange resulting from correct irrigation with appropriate spray jet adjustment. In-vivo studies revealed that the temperature deep inside the osteotomy cavity rises to only around 26–28°C when irrigation is provided at 18°C (Scortecchi 1988; Scortecchi et al. 1990).

Figures 5.6–5.8 clearly demonstrate the usefulness of supplying both the turbine and the universal syringe with an appropriate cooling medium. The minor alterations required for this can be made to any dental unit. The „clean-water systems“ commonly used in the US can be connected to the delivery pipe and integrated into the water supply. Dentists who routinely insert implants will sooner or later use a dedicated chair for these procedures. There is actually no need to connect this chair to the tap water system.

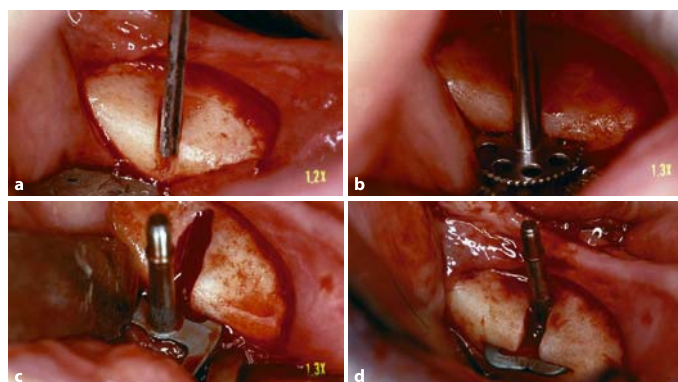


Fig. 5.2a–d. The vertical osteotomy slot is cut first. It defines the direction, the departure point and the endpoint of insertion. Subsequently, a number of horizontal cutters with incremental diameters (starting with a 7-mm cutter) are applied. In maxillary structures and on the non-working side of the mandible, it is frequently possible to establish both the vertical and the horizontal slot at once by using a combination cutter (e.g. 10 mm). Once the slots have been completed, the implant can be inserted. It is recommended to use implants that are somewhat „oversized“ in relation to the bone structure

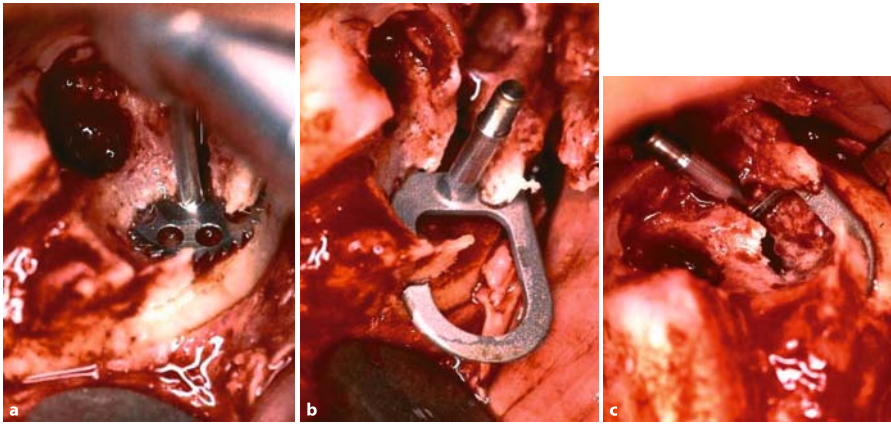


Fig. 5.3a–c. BOI tuberosity implants are introduced parallel to the slot and then twisted inside the bone to adapt them optimally to the available jaw structure

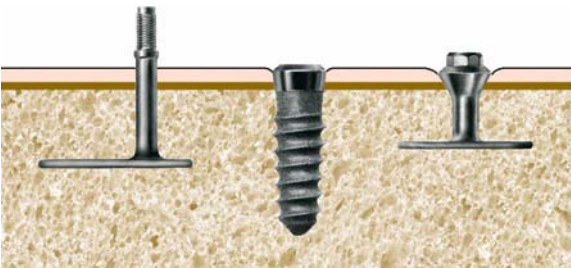


Fig. 5.4. This diagram shows the correct heights of the prosthetic connectors. For BOI implants with external threading (E types), the region of the thread is positioned as far outside the mucosa as possible. By contrast, multi-unit screw implants are inserted into the bone such that only the polished parts of the thread are located in the mucosal area. BOI implants with internal threading (ID or IDO types), like screw implants, can be submerged more deeply than ED implants. The price to be paid, however, is the additional cleaning effort required. We tend to dispense with IDO implants in favour of ED implants in patients with discernibly poor oral hygiene, immuno-deficiencies or concomitant diseases that adversely affect the treatment prognosis, as well as in smokers

The practitioner will need to consider the following points:

- Is the quality of the water from the dental unit adequate, or is a special irrigation fluid required? In most situations, a turbine and normal clean water will be all that is required to perform the entire surgical procedure.
- The decision to use a special irrigation fluid raises the question whether the procedure can be performed with the regular dental unit or whether a separate surgical unit will be required.
- The dentist must also weigh up the pros and cons for working with FG instruments (whether in the turbine or the high-speed angled handpiece) or with angled handpiece connections (i.e. the blue 1:1 handpiece).
- The turbines must feature large rotor blades to offer the required power level. Also, the bearings

of large-rotor turbines appear to be more rugged, which quickly pays off with large-diameter cutters. In our practice, we have come to use KAVO 650 and 650A as our preferred system and tend to consume three rotor heads in roughly 500 implant procedures a year.

We normally use sterile Ringer lactate as a cooling medium, which is stored in the refrigerator. Due to its composition, Ringer lactate is more benign to the bone than saline. After all, the bone harbours high concentrations of salts and proteins and is quickly drained of these substances when contact with liquids of lower osmolarity or altered composition is established.

To summarize, thanks to the availability of special surgical equipment and the option to retrofit all conventional dental units with clean-water systems, we are today in a position to conduct osteotomy procedures with high-speed rotating instruments in a clean and physiological manner (Ihde 2002). If the procedure is correctly handled, the bone will not be damaged beyond what is inevitable.

Not all bone areas are equally submissive to the cutting instruments used for osteotomy. Compressive areas (chewing side) offer the greatest and tensile areas (non-chewing side) the smallest resistance. This holds true for both jaws. Based on these parameters, the results of the preoperative functional analysis can be intraoperatively verified.

5.4

Configuration of the Load-Transmitting Surface and Threaded Pin

In the aesthetic zone, particularly of the maxilla, the threaded pins should be placed as far palatally as possible, so that the technician has freedom to optimally design the anterior dentition. To avoid

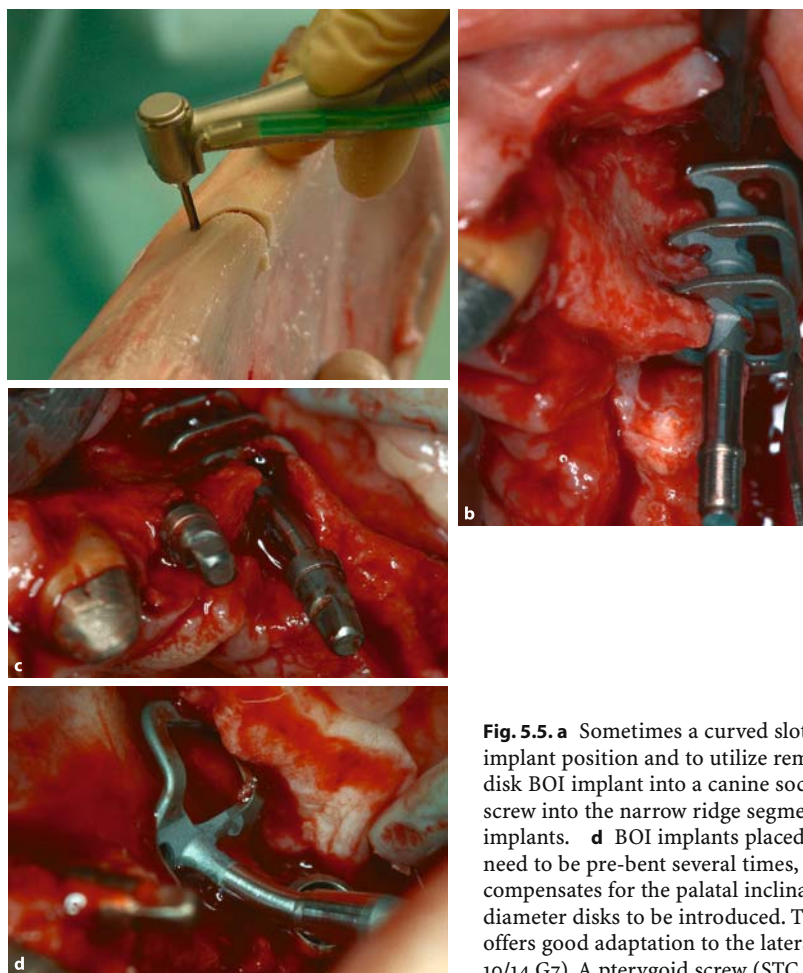


Fig. 5.5. **a** Sometimes a curved slot is required to achieve the desired implant position and to utilize remote bone areas. **b** Insertion of a triple-disk BOI implant into a canine socket. **c** Insertion of a compression screw into the narrow ridge segment to the anterior of the triple-disk BOI implants. **d** BOI implants placed in the distal maxillary region often need to be pre-bent several times, so that the curvature of the threaded pin compensates for the palatal inclination of the slot. This will allow larger-diameter disks to be introduced. The vestibular flexion of the basal plate offers good adaptation to the lateral wall of the maxillary sinus (EDAS 10/14 G7). A pterygoid screw (STC 4.1 19) is already in place distally



Fig. 5.6. Even with the cutter fully inserted, enough irrigation fluid is driven through the osteotomy slot. The cooling effect is even better when an aerosol is used. The picture illustrates a test osteotomy performed on a pig scapula

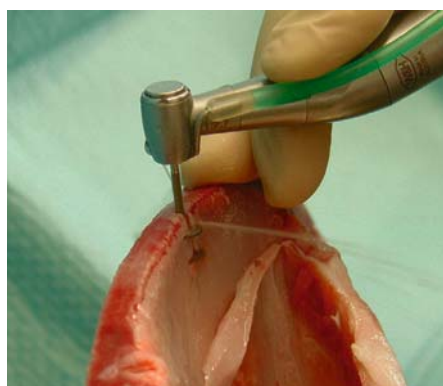


Fig. 5.7. When twin cutters are used, the irrigation fluid will not normally reach beyond the crestal disk; the basal disk has to be irrigated separately



Fig. 5.8. The basal disk of the cutter is cooled by an additional spray jet applied laterally through a universal syringe



Fig. 5.9. It takes intriguingly little to set up an ergonomically correct operator. A spittoon is not required. The clean-water system is mounted behind the instrument tray on the transverse arm of the unit

restricting tongue movements, implants should not be placed to the anterior of the canines.

With the implant designs available today, it is usually not necessary to place more than four implants per jaw. Abutments at the positions of the canines and second molars will usually suffice for strategically supported restorations. Additional implants may be indicated, however, in specific situations. Consider the following points:

- Triple-disk implants may sometimes be a useful option in the anterior segment of the maxilla due to their osseoprotective effect.
- If the immediate outcome of individual implants in terms of primary stability is uncertain, additional implants may improve the prognosis of the overall structure.
- Treatment of severe dysfunction may involve a phase of high muscle resistance while the chewing function is being reconfigured. In this situation, it may actually be necessary to „sacrifice“ individual implants to create space for the chewing muscles. This presupposes that additional implants were inserted in the first place, or the entire structure will be in jeopardy. Alternatively, the dentist may choose to leave any residual teeth in place for the duration of the healing phase and extract them later before inserting the definitive restoration. Some users, however, prefer to use implants sparingly in the initial phase to retain a maximum of “virgin” bone structure for any additional

implant procedures down the road. This strategy may be advisable if the bone volume is generally low. Both strategies have specific advantages and disadvantages.

- Some users insert five implants per jaw. In addition to the distal implant in both posterior segments, they use a total of three anterior implants, taking advantage of the anterior nasal spine in the maxilla and the heavily trajectorialized and mineralized anterior segment of the mandible.
- The best results in the distal maxilla have been obtained with 12-mm implants. The width required to secure adequate support is also offered by EDAS 9/12 und EDAS 10/14.
- The number of implants to be inserted in the maxilla also depends on the applicable disk diameters. The smaller the diameters, the greater the number of implants and/or disks per implant.
- Bone elasticity in the mandible should not be unnecessarily reduced by using rigid implant designs. Large-diameter implants should be avoided at the distal abutment position in the mandible. If they have to be used after all, the disks should be inserted at a rather deep level. Four implants in the mandible will normally suffice as strategic abutments.
- All relevant parameters such as the diameter, position and thickness of the disks as well as the number of implants and the number of disks per implant need to be matched.



Fig 5.10. **a** Two plastic flasks will normally be sufficient even for extensive osteotomy procedures. The Ringer's solution is dispensed through all lines, including the universal syringe. The irrigation fluid needs to be transferred into the empty flasks. The system can be flushed with chlorhexidine digluconate solution for cleaning. **b** This ELCO system by W&H (i.e. the smaller version) with on-board torque control is perfectly serviceable for all practical BOI purposes. The irrigation medium is supplied directly from the sterile container through the green external tube

- If the patient wears a complete denture in the opposing jaw, the masticatory forces will be relatively low. It is therefore useful to keep the number of implants small.
- Based on a total sample of 1,200 consecutive BOI implants, the probability of implant survival based on disk diameters can be summarized as in Table 5.1:

Table 5.1. Results are not broken up according to maxillary versus mandibular implants. The findings do not confirm the suspicion that implant losses involving larger disk diameters ("extension implants") may be associated with substantially greater losses of bone volume. The practitioner, however, has sometimes only bone with a width of 7 mm available. Losses, in our retrospective view, often occurred in cases, where it would have been possible to place a larger implants although this seemed not advisable in the specific situation during the operation. Note that this table does not comment on the number of base-plates but regards only the largest (or the only) base-plate of the implants

Diameter of the (basal) disk	Rate of implant loss after 3.5 years (based on all patients)
7 mm	1.4%
8 mm	2.8%
9 mm	2.3%
10 mm	1.9%
12 mm	0.2%

The length of the threaded pin must be selected such that the connection point between the implant

and the abutment/crown will be located sufficiently far from the mucosa. In this way, the mucosal penetration point of the implant remains small and at the level of the polished implant segment. Infections are thereby avoided, and the advantage of a thin mucosal penetration is optimally utilized. The point where the implant meets the crown has to be periodically monitored, since bone remodelling is likely to continue for the rest of the patient's life. Mucosal proliferation may give rise to overgrowth of the abutment and superstructure. This may block the drainage pathways and subsequently promote retentive inflammation at the implant shaft. To make things worse, fluids that cannot drain off through a crestal pathway will migrate deeper, which carries a risk of the infection spreading to the bone and basal plate. The reader is referred to Chapter 7 for a detailed discussion of treatment planning.

Another principle of implant selection is that the length of the threaded pin should always be maximized to the point of being limited by prosthetic requirements only. G6 or G7 designs are used in most situations. The only place where higher G values can be routinely used is in the anterior segment of the mandible.

If implant losses are evaluated based on G values rather than disk diameters, it becomes clear which G values are preferable. The data given in Figs. 5.11 and 5.12 are based on all structural types collectively. They represent a total of 651 BOI implants in the maxilla (41 losses = 6.3%) and 645 BOI implants in the mandible (14 losses = 2.1%).

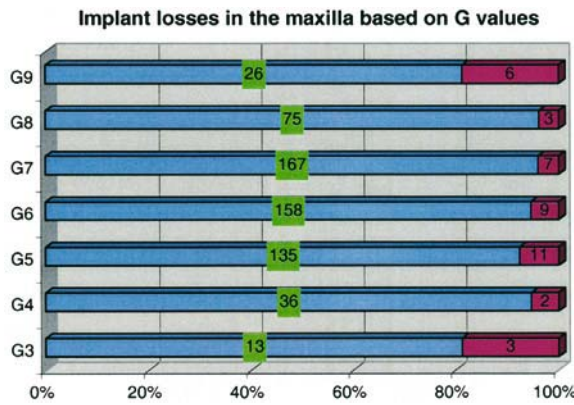


Fig. 5.11. Implants lost in the maxilla according to G values. The best results were obtained with G4–G8 designs. The illustrated data refer to external-thread implants (ED, EDS, EDAS, etc.)

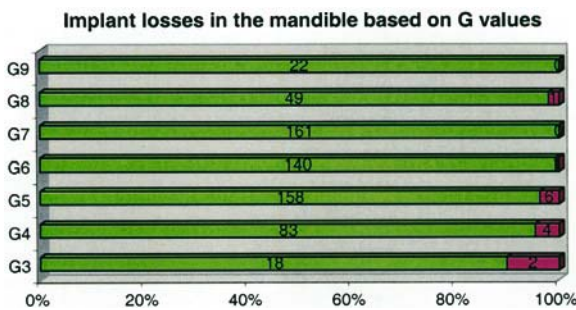


Fig. 5.12. Implants lost in the mandible according to G values. The chart leaves no doubt that the higher G values are associated with a high probability of implant survival. This is due to the flexural compensation offered by long threaded pins. Unfortunately, this length cannot be selected arbitrarily but is often limited by a reduced vertical dimension

Abutments made from Delrin (DA4, 5, 99) help to cope with the flexion of the mandible. Hence it is advantageous to equip at least one of the distal implants in a full bridge with those abutments. If more than two BOI are placed in a row in one jaw, a hypomochlion may develop. DA-abutments help to ease the forces on the BOI implant in the middle. The same problem is known from teeth: Bridges from the 3rd over the 5th to the 7th tooth show tend to harm the tooth in the middle already after some years. Some BOI-implantologists do not use an abutments on intermediate external BOI. Instead they use methacrylate to connect the bridge to the implant. Neither Delrin nor methacrylate are, however, visible in X-rays.

The following conclusions can be drawn:

- The rate of implant loss is higher in the mandible. Which structural designs offer the best results in the mandible remains to be investigated.
- The higher the G values, the lower the rate of implant loss in the mandible. The best results are obtained with G6–G9 designs. High G values offer better adaptation of the implant-restoration system to jaw flexion.
- G values in the range of G4–G8 apparently offer the greatest safety in the mandible (with G7 and G5 designs yielding slightly better and poorer results, respectively).
- The presented data reflect not only implants lost to infection or overload osteolysis but also implant fractures. Events related to mobile superstructures were also included in the analysis. In other words, any implant losses occurring after superstructures became dislodged from natural tooth abutments are also reflected in the table, even though they were not caused by the implant system as such. Excluding these cases would bring the rate of implant loss down by another 40%.
- Overly low G values carry an increased risk of infections advancing towards the basal plate. Overly high G values, by contrast, will increase the lever forces. All losses affecting G9 designs were due to implant fracture at strategic positions in the maxilla. After modifying the basal segment of these designs, we have never again observed this type of problem.

Some clinical situations require specific approaches:

- BOI implants are always positioned where the bone volume is optimal. This does not always coincide with the position that would be most desirable from a purely prosthetic standpoint. The threaded pin has to be parallelized by bending after insertion, or indeed prior to insertion if the bone structure is very weak. At any rate, this step should be performed before the definitive suturing, as there is always a chance that the disks will be slightly dislocated by manipulating the pin. In that case, the implant can still be moved back to its correct position before the flap is closed. The abutment can be unscrewed to offer better access for the bending procedure. Alternatively, the unscrewed TAP D tool can be used with or without the help of a RAT2 ratchet wrench. If ideal parallelism cannot be established, any slight deviations can be easily overcome in the fabrication and insertion process.
- Intraoral bending is not an option with internal-thread BOI designs (i.e. IDO and ID).
- If the bone volume above the inferior alveolar nerve in the distal mandible is not sufficient, the load-transmitting disk can also be placed under the nerve. This is achieved by exposing the nerve at the planned implant site and placing the threaded pin laterally in a safe position. This strategy should only be used by well-versed

surgeons with a steady hand and steady nerves who are trained in three-dimensional thinking (see Video 17).

- Implants along the maxillary are either inserted after the bone has been augmented by sinus floor elevation as described below, or they are placed inside the sinus following partial removal of the Schneiderian membrane. Which approach is taken does not depend on the residual bone volume of the alveolar crest but by the requirement that a sufficiently wide basal plate can be used to secure bicortical anchorage. If the vertical dimension of the residual bone structure is small, it is usually preferable to take the intra-sinus approach for its better drainage conditions in the event of infections. The reader is referred to Chapter 18 for a detailed discussion of these approaches.
- The intra-sinus insertion technique may sometimes lead to infections of the sinus. Since these infections must be aggressively treated, precautions must be taken for this eventuality by ensuring that appropriate drainage pathways are present. Any complications arising from infections of the maxillary sinus are invariably due to poor drainage conditions. Decongestant nose drops and rinsing with saline should be applied as the treatment of choice. In situations such as these, the dentist should preferably collaborate with a well-versed oto-rhinolaryngologist who is also an experienced surgeon. Trying to solve the problem with antibiotics is contra-indicated. This strategy can only offer palliative relief but basically perpetuates the problem. Total blockage of the semilunar hiatus may give rise to suppuration through oroantral fistulae, which may form at remote locations from the implant site. While these fistulae may also form along the threaded pins, they are more commonly observed in posterior locations with no implants in their immediate vicinity. They are a natural consequence of overpressure in the sinus, which will usually resolve after competent ENT treatment enabling the fluids to drain off as they should. If such infections are not aggressively treated, there is a risk that the infection may spread to the load-transmitting surface of the implant, eventually resulting in loss of the implant.
- The sinus can also be rehabilitated by treating the (surface-enlarged) load-transmitting surfaces with hydrogen peroxide 3–5%. A secondary augmentative procedure can be performed either simultaneously or at a later time. Augmentation into the open, previously infected sinus is not recommended.
- It is also possible to rinse the entire sinus with hydrogen peroxide (3–5%) by introducing a thin cannula along the threaded pin. On instilling a small amount of the fluid, a purulent smell should emanate through the hiatus. If that is not the case, the natural drainage pathway may be blocked. In other words, if the medication-induced overpressure cannot be discharged through the natural passage, rinsing will not be successful, and there is a risk that the overpressure may take a different route, thus spreading the pus to areas where it does not belong. If rinsing is successful, all pus will be eliminated from the maxillary sinus in a matter of minutes. The head of the patient should be brought into a position where the fluid runs together before the hiatus. The patient will want to spit out the released fluid several times. It will be necessary to ventilate the operatory well after this type of treatment.
- Probing along the threaded pin of a BOI implant or into the fistulated areas towards the implant is strictly contraindicated, thus amounting to malpractice. Such probing has no diagnostic or therapeutic significance whatsoever and is totally unnecessary. On the contrary, these measures routinely add a wholly new pathogenic spectrum to previously unaffected areas by way of cross-contamination. Unfortunately, some crestal implantologists continue to employ these probing techniques. The reader is referred to Chapter 27 for a detailed discussion.
- Single-disk implants must be placed such that disks are sufficiently far apart if the vertical bone structure is reduced. Otherwise the postoperative crestal bone cover may turn out to be inadequate, thereby promoting infections and necrosis. There is also a danger that the residual bone structure covering both disks may chip off or that infections may spread from one implant to the other, which will sooner or later give rise to mobility of the superstructure itself. Even worse, this process may eventually result in partial horseshoe downfracture characterized by isolated mobile bone areas along the maxillary ridge.
- The dentist should always strive to secure a position where at least a small part of the inserted implant projects laterally from the jaw. This configuration has several advantages. First of all, the patient will experience periosteal pain should the disk be mobilized by excessive loading. Such an alert function cannot be obtained if the entire disk surface is anchored within cortical bone. Furthermore, the jaw volume is going to increase as the masticatory forces gain momentum in the postoperative phase. Overly small BOI implants may descend in this process to the point of reaching the cancellous core of the bone, thereby losing their cortical support. Lastly, implants disconnected from the periosteal blood supply cannot offer optimal load compensation.

- Projecting implant areas may be contra-indicated in the posterior segment of the maxilla. The dentist has to assess prior to flap reflection whether or not the bulging distal portions of the maxilla are covered by attached mucosa. If they are, the same areas are going to be overgrown by close fitting structures of attached gingiva once again after implants have been inserted. Any pointed projecting disk segments might sooner or later push their way through these structures and thus become prone to infection. Any projecting disk segments in such areas must therefore be meticulously avoided. If they are inevitable, the affected bone structure must be augmented (right away or at a later time). Another potentially helpful approach would be to cover the disks with membranes designed to keep the mucoperiosteal flap „at arm's length“ until new bone has formed underneath.

During wound closure, a hole is punched into the flap in the area of the threaded pin, allowing the flap to be drawn over the implant, thereby obtaining stability against tensile forces. Then the suture is performed on the medial aspect. At implantation sites that are compromised by soft-tissue infection, the wound closure is left somewhat permeable to permit a certain degree of suppuration and autocleaning of the wound.

The sutures are removed as soon as possible. If no tensile forces are observed on the wounds, the sutures can be removed on the first postoperative day. If the patient smokes in the postoperative phase, it may be necessary to wait for several days before the sutures can be removed. Our recommendation is that patients should not smoke for at least 6 weeks before and 3 weeks after the procedure, knowing full well that this recommendation is virtually never heeded. Compromised wound healing, often associated with large pyogenic granulomas, is a common observation among smokers, but also among patients who have worn heavily loaded dentures over many years or have been subjected to multiple extractions. The affected regions show a petechial bleeding tendency, which

may be asymptomatic or recurrently symptomatic and is usually noticed by the patients themselves, especially during brushing. An appropriate treatment modality in these situations is to carefully strip the granulomatous area by suprapariosteal electrosurgery, followed by etching with hydrogen peroxide 30% or chromium trioxide. This technique to stimulate healing is even effective with large granulomatous areas. Mild etching with H₂O₂ 30% may be all that is required. The affected tissue is apparently neither rehabilitated nor rejected in this specific type of mucosal reaction. In this way, the chronic infection in the former flap area will persist for many days or indeed weeks if no treatment is provided.

Etching gives rise to foam formation in the affected areas while no response is seen along the non-affected mucosal structures.

Bone healing in the postoperative phase of BOI treatment is a cascade-style process that invariably unfolds in a uniform manner. If the process is disrupted by any interfering factors, the original condition of the tissue can no longer be restored. The healing process will proceed in an atypical manner, usually involving connective tissue repair. The only way to restore the state before the healing process was disrupted is to create another injury associated with bleeding. Any newly formed connective tissue areas have to be removed, as they would inhibit bone formation in a competitive manner.

5.5

Combination with Screw Implants and Bending of Base-Plate Areas

In case that narrow bone areas are located between extraction sockets, KOS-screw implants are an alternative to BOI. Figures 5.14 and 5.15 show an example for this strategy.

In situations in which the residual bone is insufficient, the dentist must find a method of horizontal enlargement to accommodate the implant.

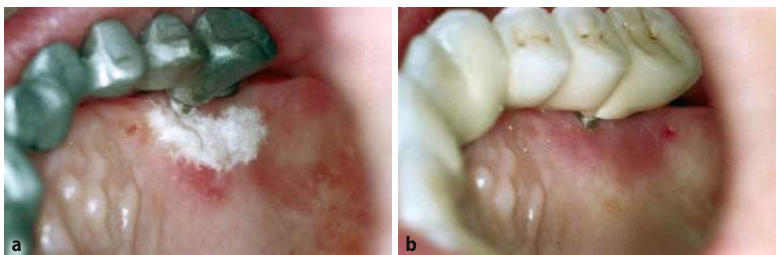


Fig. 5.13a,b. Inflamed mucosal structures are still visible as the framework is tried in. They are etched with H₂O₂ 30%. By the time the bridge is inserted, the inflammation has largely resolved. Otherwise, the etching step would have been repeated, or the tissue would have been removed by electrosurgery

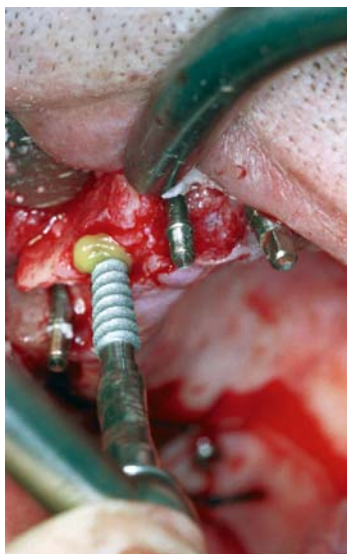


Fig. 5.14. Administering Terracortril-Salbe to the surface area of KOS-screw implants is an option. This fatty cream enhances the screwing-in procedure



Fig. 5.15. KOS screw implants are equipped with the same head-type that is available for BOI-implants also (TSD4). This makes it easy for the dentist technician and the surgeon, since all tools and the analogs are the same. Some types of KOS-screw implants are equipped with a bendable abutment-head

The most obvious approach is to adapt the implant, which should be as large as possible, to the bone structure by vestibular (or, less frequently, palatal) bending. To avoid damaging the available bone structures, it is recommended to subject the implant to slight pre-bending at the desired location before inserting it. In very fragile bones all of the bending must be done before insertion the implant at all.

Unless the insertion path of the implant is perpendicular to the planned insertion path of the superstructure, the threaded pin has to be subjected to slight pre-bending as well. After the implant has been fully inserted and bicortical anchorage obtained, the projecting part can be adapted to the zygomaticoalveolar crest.

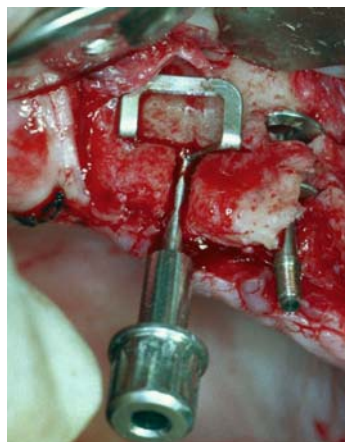


Fig. 5.16. After full insertion of the implant, the disk projecting on the vestibular aspect is bent. Those adapted implant surfaces can be additionally treated by secondary augmentation at a later time. The bending alters the force distribution inside the ring, rendering the implant more rigid. The risk of implant fracture can be reduced by using designs with several web bars (EDADS) for this manipulation whenever possible. The bar near the shaft is anchored in the vestibular cortical bone while the bent segment offers stability against lateral forces. Alternatively, if the dentist chooses not to bend the projecting parts, the bone areas covered by the periosteum in a tent-style fashion can also be subjected to a primary or secondary augmentation procedure. Contact of the vestibular disk segments to the cortical bone should be re-established for the ring structure to recover its shock-absorbing properties (vestibular struts may be bent also into the direction of the top of the crest: see Videos 7 and 11 for details)



Fig. 5.17. On revisiting the site after around 6 months, the bent implant segment has not been overgrown by bone (yet), while the vertical slot has nicely healed up. A secondary augmentation procedure would be possible but is not immediately indicated

5.6 Intraoperative Bleeding

While there is always a risk that any vessels near the surgical site may get injured during the procedure, this risk is particularly high in situations of reduced bone volume. In this section, we shall discuss the various anatomical structures that pose a risk during surgery, and we shall see how complications related to bleeding can be avoided and treated.

- **Palatal artery**

The risk of vessels being injured is especially high in the presence of vertically resorbed bone. One way of approaching the area is by not deflecting a flap on the palatal side. This is possible, if reliable CT pictures are at hand and give enough information about the necessary width of the bone. Any bleeding reactions can be dealt with easily if the palatal flap is not fully dislodged. The lateral cut must be performed carefully, so that any injuries to this vessel (increased bleeding) are immediately noticed. On the other hand, such injury demonstrates beyond doubt that bicortical anchorage has been reached.

When bleeding from the palatal artery is noticed, the cutting procedure for the horizontal osteotomy has to be stopped immediately. The implant can be inserted right away. This will stop the bleeding in the vast majority of cases as the empty osteotomy slot is filled. Any residual bleeding will be dealt with by the process of wound closure. In those rare cases where complete haemostasis cannot be achieved, an alginate impression can be taken to fabricate a dressing plate (e.g. from a deep-draw plate), which should be large enough to reach the reflection fold, is screwed to the implant(s) with the help of the abutment(s) and lined with tampon swabs if necessary. This procedure will reliably stop the bleeding. Bleeding at individual surgical sites can be stopped with local dressing plates fabricated from plastic foil (using, for instance, the sterile package of the Diskos implants or the suture material), to be screwed to the implant with the abutment. The dentist may choose to use a TSD99-type abutment to optimize the pressure exerted on the soft-tissue structure.

Any bleeding into the maxillary sinus cannot be stopped at the source. We have never experienced any cases of bleeding through the semilunar hiatus into the pharynx or from the nose in our practice. Rather, the blood inside the maxillary sinus would always coagulate within a short time, thus obstructing the natural passages.

The second approach to avoid bleeding is by defecting the palatal mucosal flap and mobilizing the vessels. This way they can be saved from

damage. Note that deflection of a flap will always enhance remodelling of the exposed bone area.

- **Incisal artery**

This vessel is almost invariably injured when implants have been placed in the area of the anterior nasal spine. As a general rule, bicortical anchorage of BOI implants can only be realized in this area when the cortical bone structure on the palatal aspect beyond the artery is reached. Since this vessel is usually rather small and its internal pressure low, the bleeding can be effectively stopped by simple suturing. Anyway it is for aesthetical reasons in many cases not recommended to place implants between the (upper) canines. In rare cases patients report persistent pain after the placement of implants near or in the incisal canal. This pain seems to stem from an immobilisation of the bones at the sutures and not from the canal or the nerves. Removal of the implant is on possible treatment of this type of pain.

- **Mandibular artery**

When implants are placed just above the mandibular canal, there is always a chance that the canal is invaded by the cutting instruments. Injuries to the nerve are rare in this connection because the nerve "protects" itself quite successfully, as long it is not anaesthetized by a mandible block. Much more common are bleeding reactions caused by (painless) injuries to the mandibular artery with its implications for the further handling of the surgical procedure. Since the osteotomy is not normally completed by the time of bleeding, the question whether the implant procedure should be continued at that specific site must be carefully reconsidered. After all, BOI implants placed at a site where the bone mandibular canal has been opened may give rise to thermal sensitivity in that area down the road, as any physical variations will be transmitted through the implant shaft right to mandibular nerve if the canal is not enclosed by bone.

The dentist should therefore always consider the option of creating a new osteotomy, thus placing the implant further distally or mesially, on being faced with bleeding from the mandibular artery. The bleeding as such can be easily stopped by just closing the osteotomy slot. In some patients, the mandibular artery and nerve pass along in separate canals, which cannot be diagnostically identified (Sanchis et al. 2003).

- **Facial artery**

Injuries to the facial artery are a particularly unpleasant kind of complication. Inexperienced surgeons will initially fail to understand how this could happen. If extensive flap reflection is performed in situations of heavy mandibular

resorption, then the flap will remain under considerable tensile stress due to the retracting force exerted by the mental nerve. If the assistant or surgeon loses control of the protective spatula during the osteotomy, the cutter may enter the vestibular cheek area where it may invade the facial artery of its associated vein from inside. Both types of injury will give rise to profuse bleeding at high pressure.

The immediately required treatment in these situations is to compress the affected vessel against the border of the mandible. The compression has to be maintained for at least 20 min. If the bleeding is still not stopped by this, the flap must be sutured without unnecessary delays. The compressive force must not be released before the suture is completed. If this does not solve the problem either, the vessel needs to be visited and ligated through an extraoral access (after being opened up if necessary). The patient should be monitored for some time subsequently.

- **Submandibular arterial plexus**

Penetrating the lingual cortical bone structure while applying the cutter for an interforaminal implant procedure carries the risk of injuring submandibular vessels. As a matter of fact, several patients are on record in the literature on crestal implantology as having died after such incidents (Weibrich 2002). What makes this situation so problematic is that no bone structure is present against which the vessel can be compressed for haemostasis. Ligating one supplying vessel is usually not possible. Even if both supplying vessels are ligated, however, the situation still remains life-threatening because compression of this area is difficult. The submandibular vascular plexus will keep bleeding internally after suturing, thus displacing the soft-tissue structures, so that the tongue and floor of the mouth may be elevated dramatically to the point of obstructing the airways. It is necessary to monitor the patient on an inpatient basis after incidents of this type. Intraoperatively, the dentist can establish by way of differential diagnosis that the source of bleeding is really in the submandibular plexus, since profuse bleeding may also emanate from the mandible itself (Video 3). Bleeding from the submandibular plexus can at least be stopped in the osteotomy area by compressing the lingual soft-tissue structures against the mandibular bone, thereby disrupting the vestibular bloodstream from the implant site. Bleeding from the mandible itself, by contrast, will not respond to compressing the lingual soft-tissue structures at the suspected site of perforation (see Video 2 for details on distinguishing the source of bleeding in this area). What is less well-known is that one or two smaller arteries usually enter

the mandible from the lingual side. These arteries may be 1–1.8 mm in diameter and occasionally cause massive haemorrhages (Lustig et al. 2003), which, however, usually quickly subside once the implant is placed and the mucoperiosteal flap is sutured closed.

Good planning of the osteotomy by CT imaging can be helpful to avoid arterial bleeding particularly in the hands of novices. The soft-tissue structures in the mandible can also be protected with a spatula or raspatory after lingual flap reflection. If flap reflection is not considered appropriate, the assistant (fourth quadrant) or dentist (third quadrant) can use a finger to ascertain by “counter-palpation” when the soft tissue is reached on transversing the contralateral cortical bone structure.

Dentists who are just starting out in BOI therapy and whose surgical experience may still be limited may be afraid of damaging some of the larger blood vessels at the surgical site. This fear can go so far as to result in BOI implants not being inserted where they should from a biomechanical point of view, or not in a correct bicortical position. However, this does not help the patient. Experienced operators are never afraid of blood vessels or nerves; they will operate carefully and circumspectly and place the implant where they will function best. The cause of any haemorrhages that may occur will have to be examined and the necessary measures taken to control them.

In situations of severe periodontal damage, the soft-tissue structures may be mellowed to the point of allowing diffuse bleeding even if coagulation is only mildly impaired. The dentist should first attempt to establish a large contact area of the wound margins by suturing the site around a wide margin of healthy tissue. If this first attempt is not successful, any additional sutures are usually useless. Actually, they would be more harmful than beneficial by traumatizing the tissue even more and creating additional holes. Active coagulation is not usually helpful either but carries the risk of propagating the injury to segments where the lumen of the affected vessels is larger. Pressure tamponade applied to the bony base from an extraoral direction offer better chances of success, notably if the bleeding is located vestibularly to the bone. Good results have been obtained, for instance, with modified orthodontic devices such as headgears or chin caps. The support areas of these devices can be expanded with acrylic resin to include the affected areas, then supported against the neck or occiput.

Note

1. Intact coagulation is a mandatory requirement for all procedures involving BOI implants.
2. It is necessary to pay attention to the blood vessels and nerves during an operation. It is dangerous, however, to be afraid of them.

Whenever profuse bleeding occurs, the dentist has to reassure that the patient is not on any type of anticoagulant drugs. A great many patients who have taken Aspirin Cardio over many years will not even realize that this type of medication may be relevant in connection with dental implant therapy. Some general practitioners strongly believe in anticoagulation therapy and prescribe those drugs to their patients on a lifelong basis. While the question for how long a patient has been on anticoagulant drugs is invariably answered in detail, the second question for how much longer this therapy is going to be continued will usually draw a blank stare.

The dressing should be left in place no longer than is necessary (1–2 days at the most) so that suppuration from the surgical site and flap area is not unduly impeded. The pressure exerted by the dressing can be increased by using a TSD99 abutment or by folding the plastic layer several times. In the maxilla, the dentist may alternatively choose to apply laboratory-made dressings covering several implants.

5.7 Medication

Antibiotic treatment is commonly recommended in dental implantology although a real benefit has never been established. For this reason, we only use antibiotics when specific medical reasons argue in favour of such coverage, usually after consulting the general practitioner, who may even choose to define the type of antibiotic to be used. Numerous recommendations for antibiotic treatment have been provided in the literature. In our own practice, we have performed around 2,000 implant procedures without antibiotic coverage. We have not observed any disadvantages. Postoperative swelling can be avoided by subcutaneously injected corticosteroids.

The implant procedure as such can be performed under general anaesthesia, sedation, nitrous oxide analgesia or local anaesthesia. We have found that it is generally simplest to use local anaesthesia, which allows the patient to actively keep his mouth open and control the movements of his tongue.

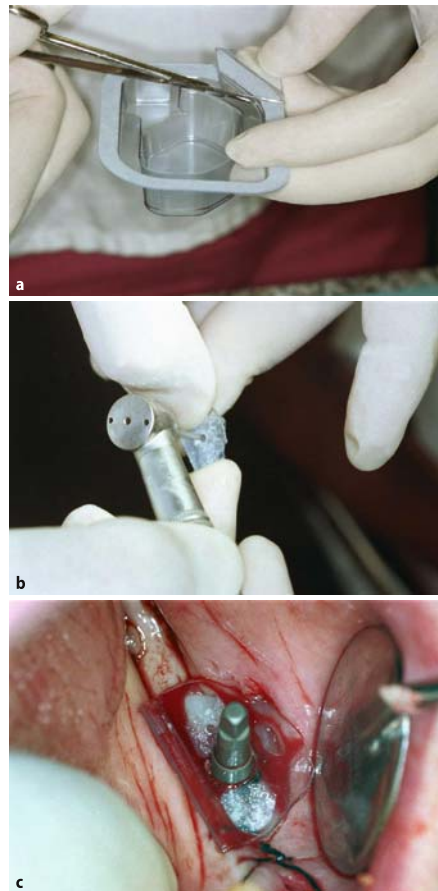


Fig. 5.18a–c. A local dressing plate can be made from the plastic wrapping of the Diskos implant and applied together with the abutment by establishing the screw connection. After an appropriate piece of plastic has been cut out and folded once, a hole is cut into both layers through which they can be slipped over the threaded pin and secured with the abutment.

Patients under sedation or nitrous oxide analgesia are more likely to swallow objects such as screws or bone fragments than non-sedated patients. General anaesthesia, by comparison, offers the advantage that the pharynx is stopped up so that the patients cannot possibly swallow any objects. Furthermore, the blood pressure can be gently and safely reduced under general anaesthesia, which can be beneficial in extensive procedures. On the downside, infranervial implant placement will involve more extensive exposure of the mandibular nerve if performed under general anaesthesia, thereby weakening resorbed ridge structures even further.

One strategy that we feel has been very useful in all our surgical procedures is to apply oxygen 3 l/min continuously through a nasal probe. This precaution will keep blood oxygen concentrations stable even in critical situations, which does a great deal to reduce the patient's stress level.

Prophylactic application of mild nitrous oxide analgesia is a useful precaution in patients with a history of heart disease. The rationale for this is quite simply to alleviate any painful sensations, thereby eliminating the possibility of shock-induced acute symptoms. Modern nitrous oxide systems offer digital monitoring of the gas mixture and acoustic signals when one of the gases is used up.

Some users recommend treating the patient to abundant amounts of warm tea and dextrose to strengthen his overall constitution for the procedure. It is consistent with our own observations that some patients are so scared by the prospect of undergoing oral surgery that they do not eat or drink before the procedure, thus coming to the office ill-prepared. We therefore advise our patients to eat and drink “as usual” (unless deep sedation or general anaesthesia is planned) so that their normal diurnal patterns are not upset during the treatment. Administering warm water during the operation every 20–30 min helps the patients autonomic nerve system and the matrix to stay in balance. The same, by the way, also helps us doctors during lengthy surgical interventions. So both patient and the doctor should take a short break and refill their liquid reservoir.

In the postoperative course, the patients are treated with analgesics. Depending on an individual’s pain sensitivity, Ponstan (mefenamic acid) or more effective drugs such as Lamaline are used. Most patients will be free of pain on the first postoperative day. Postoperative pain will be lower if the procedure was performed swiftly and with liberal flap reflection. Dento-hexidine gluconate is recommended for anti-infection prophylaxis from the first postoperative day.

Zones of major swelling can be quickly resolved by lymphatic drainage in the hands of a well-versed dentist or dental assistant. The important part is to



Fig. 5.19. Matrix N₂O mixer system with user-friendly control and display panel



Fig. 5.20. The Matrix system can be additionally fitted with an oxygen demand valve to effectively deal with emergency situations. Two flasks of oxygen and nitrous oxide each will ensure that the supply is never interrupted



Fig. 5.21. This CRITICARE system is used to monitor cardiovascular function. Oxygen saturation and heart rate are useful parameters for routine dental procedures. The ECG function is not required

drain the drainage regions in the lower neck area first before addressing the swelling in the cheek area. A total of three or four daily sessions of 15 min will help to quickly eliminate the swellings and, above all, to reduce the obstructive pressure. Patients who are susceptible to swellings can be treated by lymphatic drainage even postoperatively.

If silk sutures are used (e.g. 3.0), they should be removed on the second postoperative day at the latest. As no tensile forces will act on the mucoperiosteal flap if the flap was drawn over the threaded pins of the implant, the sutures can be removed on the first

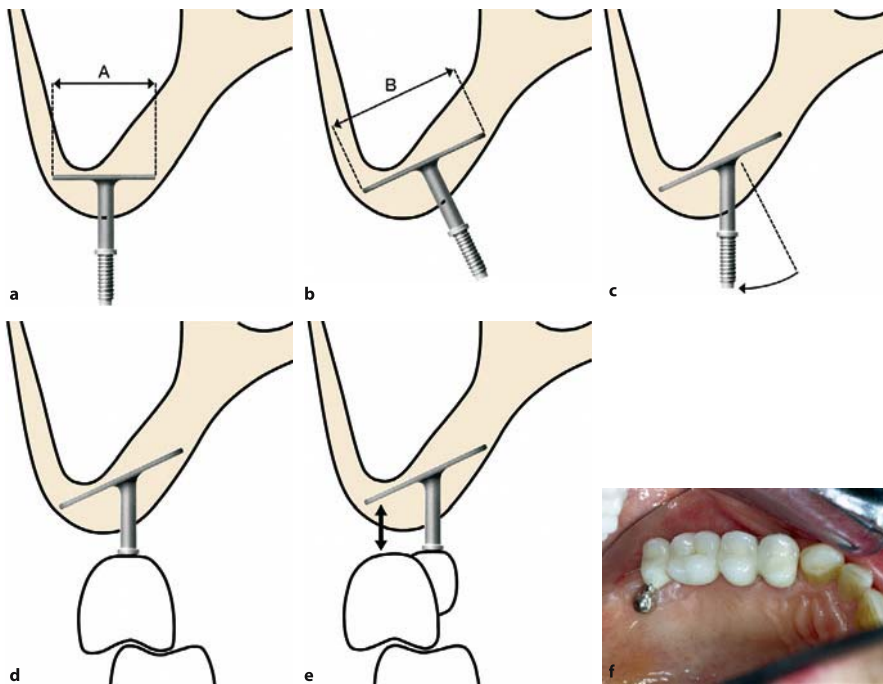


Fig. 5.22a–f. The most distal BOI implant in the maxilla should always be palatally inclined because the selected disk diameter should be as wide as possible (a, b). The threaded pin will no longer interfere with the tongue once it has been bent to obtain parallelism with the residual teeth. There is still enough space to position the superstructure next to the threaded pin. The implant type should be selected such that the centre of gravity of the prosthetic work will be located above the supporting polygon of the implants base plate (e, f). Often it is not possible to cover the connection between implant and restoration with ceramics. Adding ceramics would cause further increase in the size of the bridge, thus interfering with the functional pathways of the tongue

postoperative day. Synthetic suture materials are recommended if the sutures are to be left in place longer than that (e.g. because the maxillary sinus was opened during the procedure). Resorbable suture material is not appropriate because the resorption would give rise to inflammation.

5.8 Implant Positioning for Prosthetic Treatment

Because horizontally reduced bone volume is present or will be present after teeth have been extracted, there should be no problem placing the superstructure before the ridge. The small diameter of the threaded pin is one of the greatest advantages of external-thread BOI implant designs. Thanks to its thinness, the threaded pin can be inserted into the bone further palatally/lingually than the previous position of the dental roots. Figure 5.22a illustrates a partial crown in the maxilla for which the threaded pin had to be placed far towards the palate. Furthermore, it had to be palatally inclined. The vast majority of patients have no problem with this implant position if no rough or sharp surfaces

are present. Of course, the ring disk is located below the artificial crown at 27 after all to ensure the structural integrity of the bridge but is no longer visible following flap closure.

5.9 Injury to Adjacent Teeth

In our work with BOI implants, we occasionally had the bad luck of inflicting damage to adjacent natural roots. This type of mishap cannot be ruled out with certainty even in the hands of circumspect users with well-trained eyes. However, we did not observe any major postoperative problems in any of these cases. A number of histological tests failed to establish any undesirable consequences in most of these situations, particularly when the root dentin rather than the pulp was affected. The reader is referred to Chapter 23 for a detailed discussion of these tests. Any injuries to teeth by the BOI osteotomy procedure allows the surrounding bone structure to grow into the created gap and thus into the tooth. Problems are likely to arise if such teeth need to be extracted down the road.

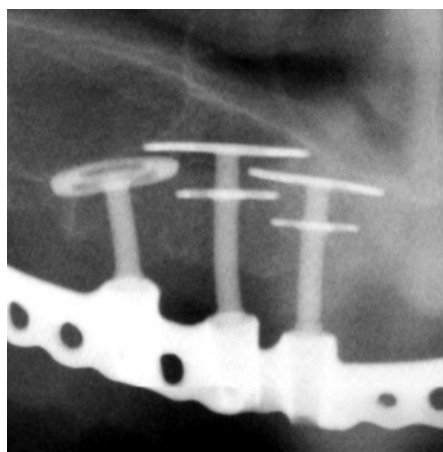


Fig. 5.23. It is perfectly possible to place several BOI implants side by side with the disks overlapping. This strategy needs practice, however, because the vertical implant components cannot be inserted in a parallel manner in jaw areas with different vertical orientations. This also has implications for the horizontal implant segments. If the vertical divergence is too pronounced, horizontal contact between the disks is more likely. Because the disks of rounded implant designs (ED, EDD, EDDD) are widest in the centre of the jaw, the sequence in which the implants are inserted is also a relevant factor. It is recommended to perform all osteotomies before any implants are inserted. Note that the bone-orienting effect of the masticatory force may overlap or be cancelled when implants are positioned closely side by side. The risk of harmful overlapping tends to be small, however, in cortical bone structures that are subjected to heavy macrotrajectorial stresses

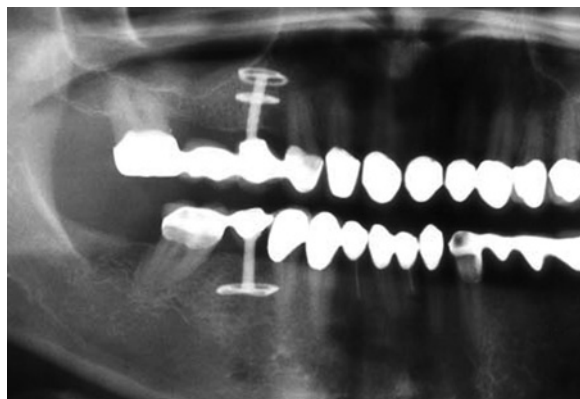
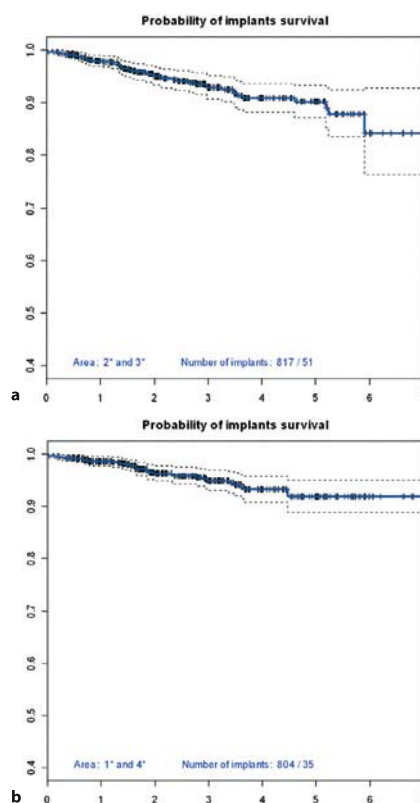


Fig. 5.24. Situation at the 5-year follow-up. The disk of the BOI implant at 46 is partially located in the distal root segment of tooth 45

5.10 Intraoperative Vision

Whenever implants are lost, there are usually several reasons involved. Based on a total of 1,621 consecutive implants placed in our practice, we addressed the question how the left and right sides of the skull compared in terms of implant durability. The surprising result was that the rate of implant loss was substantially higher on the left side, i.e. on the side facing away from the dentist. In fact, nearly twice as many implants were lost in the second and third quadrants than on the right side. It seems possible that the surgical procedure may be less successful on the left due to limited vision of the surgical site. Another possible cause may be that the dentist starts out working on the right and may be slightly fatigued by the time reaches the left side. We do think, however, that the first explanation is more plausible. Presumably, the dentist has greater trouble achieving the prosthetic treatment objectives on one specific side because the intraoral field of vision is not bilaterally equal. We attempt to keep the total number of implants large enough so that minor



errors in the prosthetic work are outweighed by the overall system. At any rate, it appears that much of the outcome depends not so much on the implant system but on the quality of the physician's work and the patient's compliance. As an explanatory note, the Kaplan-Meier curves illustrated in Fig. 5.25a,b exhibit more pronounced steps for early than late implant losses.

5.11 Analysing the Causes of Implant Loss

An analysis of the causes why the BOI implants presented above were lost yields the following result:

Cause #1: Deficient planning. This category comprises treatments where:

- An insufficient number of implants was placed given the history of the local bone supply, the masticatory pattern or the situation in the opposing jaw.
- The rigidity of the implants relative to each other and to the jaw was chosen incorrectly.
- The implants in stock are not the right ones or too few; the existing implants do not actually allow inserting the disks in the basal bone areas.
- Teeth under bridges planned to include natural abutments later turn out not to be sufficiently stable. However, if tooth mobility occurs, there is a risk of subsequent damage, with overload osteolysis or BOI implant fracture a possible consequence. Particularly critical evaluation is required for endodontically treated abutments with or without endodontic posts.

Cause #2: Deficiencies during surgical intervention. This category comprises treatments where:

- Bicortical anchorage was not achieved.
- Implants were not placed at the strategic positions.
- The G value selected is too small.
- The basal plate inserted is too small.
- Impression material was pressed into the fresh wound. (Do not use thin-flowing silicones immediately after surgery; preferably use irreversible hydrocolloids or silicone putty materials.)

Cause #3: Prosthodontic problems

- Insertion of restorations that are under stress or tension – this may subsequently result in implant fractures or overload osteolysis.
- Incorrect adjustment of masticatory function.
- Patient insisting on detrimental masticatory functional habits.
- Insufficient adjustment/buildup of occlusal surfaces in response to realignments in bone trajectories or relative shifts in the position of the restoration.
- Installation of masticatory surfaces of unequal length on contralateral sides.

System-related causes of implant loss: With crestal implants, slow, but persistent bone loss along the vertical aspect of the implant (so-called chronic peri-implantitis) is one of the primary reasons for implant loss. No such system-related causes of implant loss were found for BOI implants ever.

Diagnostics

6.1

Introduction

The purpose of diagnosis is to explore an objective against the background of a strategic task. In accordance with this “military” definition, the dentist will not consider all the factors that may conceivably be relevant to the treatment, but only those that will help him to achieve the treatment objective. By the same token, the fact that a treatment objective can be achieved is not enough, but the dentist will only consider those objectives that will actually benefit the patient.

6.1.1

The Strategic Task

The quintessential treatment objective will be to restore a balanced and efficient masticatory function. This objective can only be achieved through fixed masticatory surfaces. BOI implants are much more suitable than crestal implants for this purpose because the bone structure required to insert these designs is virtually always present.

The requirements in terms of preoperative diagnosis will depend on the complexity of the individual case and the experience of the surgeon. If the available bone volume is sparse, it will be difficult to plan the surgical procedure in a detailed manner. However, since there is no need for the emergence points of BOI implants to coincide with the location of the restored crowns, the dentist is always in a position to utilize the available bone structure without making any major concessions to the prosthetic requirements. The surgical procedure is greatly facilitated by this.

6.1.2

Exploring the Treatment Objective

The clinical examination needs to address the following important questions:

- Are there any teeth whose prognosis is good enough that they can be confidently included in the restoration? What type of restorative structure should be used?
- If teeth are not included, what measures can be taken to ensure their positional stability (e.g. occlusion, splinting, inclusion in a bridge)?
- In which bone areas should the BOI implants be anchored? The prognosis in both jaws is especially good in the canine and second molar positions. While the anterior segments offer good conditions for anchorage as well, implants in these areas may severely restrict the freedom of prosthetic design. The positions of the premolars and first molars are relatively unstable in both jaws.
- What is the current functional state of the masticatory system?

6.2

Orthopantomographs

Our recommendation is always to obtain a panoramic radiograph prior to any kind of major restorative treatment. Based on these images, the dentist can evaluate the vertical bone structure available at the selected level of the planned implantation site and extract a wealth of information on the following functional aspects:

- Distances from any endangered neighbouring structures.
- Differential size of condyles indicating a preferred chewing side and functional imbalances (see also Chapters 10 and 17).
- Differential mineralization of cortical structures indicates unilateral function;
- Differential length of horizontal branches indicates a long history of unilateral chewing;

The panoramic image will normally offer enough information for mandibular restorations. In the maxilla, additional tomograms may be useful to refine the diagnosis or even to monitor the course of therapy.

Dental films may be useful to identify any problems on individual teeth or implants. They also help to detect any persistent intrabony inflammations and their products as well as residual root structures.

6.3 Panoramic Radiograph of the Skull

An overview of the cranial structures may be useful in situation where the functional and symmetrical relations of the skull are not entirely clear. The details contained in these images are also important if the occlusal relations and the vertical dimension need to be readjusted. The cranial structures can be viewed by obtaining panoramic frontal and lateral radiographs of the skull.

The frontal panoramic radiograph provides a good overview of the cranial symmetry in the frontal plane. By evaluating the muscle attachment areas, conclusions can also be drawn about the distribution of chewing forces.



Fig. 6.1. Differently pronounced attachments of the masseter muscle indicate a long history of unilateral function and asymmetrical skeletal relations

6.4 Lateral Teleradiographs

The lateral teleradiograph offers information on the true skeletal bite relations. If an increase of the vertical dimension is planned, it can be used to simulate the effects on the overall cranial structure and to evaluate the chewing level. This type of image helps the dentist to select appropriate implant positions and implant designs (G-values) particularly in situations where the space available in the distal segments is limited.

6.5 Palpatory Examination

As the soft-tissue structures of the mandible can be readily manipulated, the conditions for palpating the bony structure are very favourable. It is always necessary to palpate the width of the jawbone in the area of the mylohyoid line prior to inserting any implants in the distal mandible. Also, the dentist needs to explore the direction of the underlying bone. The bone structure around the distal attachment of the mylohyoid muscle with its medially tapering shape is well vascularized and maintained stable by muscular stimulation, thereby offering ideal conditions to accommodate the lingual disk segment of the distal BOI implant. Bicortical anchorage can also be readily obtained in this area because the bone extends further laterally above and below the target area, so that problems are unlikely to occur even if the implant is not inserted deep enough. This is only true if the implant is seated in sufficiently far distally and is truly positioned in or below the termination line of the white line.

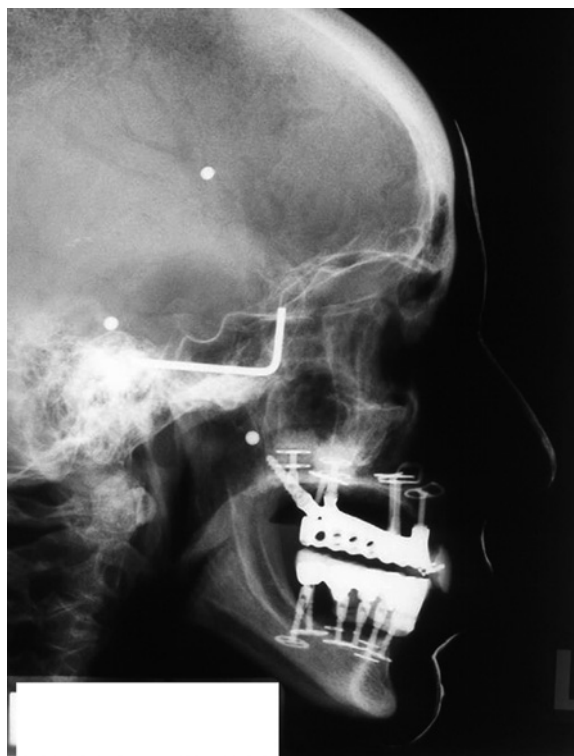


Fig. 6.2. Lateral teleradiographs should be obtained before and after implant therapy to check the orientation of the bridge in relation to the relevant planes. In addition, the dentist may want to apply contrast medium (e.g. barium slurry), which in this example is used to visualize the facial profile

In the anterior segment of the mandible, pits of varying sizes must be expected, some of which may contain unpleasantly large vessels of the arterial anastomosis. It is therefore always necessary to palpate this area thoroughly, unless it is planned to dislodge the mucosa on the lingual side of the

mandible during the procedure and protect the soft-tissue structures with a raspatory.

The conditions for palpatory examination are much less favourable in the maxilla where the palatal soft-tissue structures are thick and hard. The palatal artery, which tends to be concealed below a half-open bony canal, is virtually never palpable. Whenever the situation is unclear, the only way to explore the bone structures is by dislodging a flap. The implant site for the tuberopterygoid screw cannot be viewed either on a dental film or on an OPG. The only way to explore this area, should the need arise, is by tomography.

6.6

Functional Diagnosis and Restorative Alternatives

The first parameter to be established is whether the midlines of both jaws coincide. The labial frenum will usually suffice as reference point. It may be necessary to disregard this parameter if any teeth are missing unilaterally due to agenesis or extraction because any midline shifts associated with these situations cannot and must not be corrected by prosthetic means. The same applies if the OPG reveals that the horizontal branch of the mandible is not equally long on both sides of the jaw.

Deviations in the opening and closing movements of the mouth are the main diagnostic criterion indicating the presence of functional problems. This statement is true regardless of whether or not the dysfunction is symptomatic or asymptomatic. Pain is strictly confined to the working side.

Elongation of teeth can be observed on the non-working side where the intrusive effect of the masticatory function is less marked. Since the anterior segment (i.e. canine to canine) of the maxilla is always activated as a whole, it is mainly the central and lateral incisors of the non-working side that become elongated. Posterior teeth, by contrast, will always become elongated collectively. The occlusal plane will deviate from the horizontal line in these cases, taking a cranial course on the working side and a caudal course on the non-working side. From a frontal perspective, this type of occlusal plane will come across as an oblique line although it is really a winding line (see Chapter 10 for details).

Lateralization of the dentition can also be observed on the working side, due to the fact that the intrusive forces are unilaterally stronger. This development may cause prosthetic problems, since the former working side will be overly lateral relative to the mandibular teeth after the midline has been adjusted with a view to re-establishing a physiological function. In difficult situations, a correctly adjusted midline may

even give rise to lateral non-occlusion. Potential treatment alternatives would include wide bridge elements, medialization of the bridge relative to the bone, or orthodontic pre-treatment. Readjusting the midline will always result in a unilateral increase of the vertical dimension if teeth are still present in the maxilla. The minimum requirement with regard to the vertical dimension is defined by the elongated side (i.e. the former non-working side). In most of these situations, new laterotrusion facets will need to be established with abrasive instruments.

Unilateral extractions on the non-working side will invariably give rise to tilting of the molars distal to the extraction socket, with the distal cusps gaining more vertical space. The premature contacts resulting from this development may cause the mandible to become decentralized in all spatial directions, thus creating locked bite situation. The teeth on the working side are, by contrast, more likely to undergo bodily movements in a lateral direction (i.e. translation movements).

The condylar angle is large on the working side because the movements taking place in this area are confined to rotation. The angle on the non-working side, by contrast, is very flat because the translation movements dominating this area counteract the development of a steep tubercle.

This situation results in different AFMP angles on both sides of the jaw. The angle is always larger on the non-working side due to the elongation and medialization of teeth. The effort required to chew on this side becomes even greater, and the tendency to retain the unilateral chewing pattern is further reinforced.

Age-related diastemas may form through periodontally induced protrusion and elongation in addition to physiological abrasion, which will cause the teeth to become narrower even in the absence of periodontal problems.

6.6.1

Non-correctable Dysfunctions

Any treatment plans involving the use of BOI implants should be reconsidered if a balanced function apparently cannot be restored by any means. Possible reasons include efferent or afferent nerve dysfunction, paralysis of muscles (e.g. after polyomyelitis), or dissection of muscles/jaw segments. All these factors can create situations in which a balanced masticatory function is either out of reach or cannot be properly controlled. Restorative therapy based on strategically positioned BOI implants is not indicated in these cases. Instead, an attempt should be made to maximize both the number of inserted implants and the number of disks per implant, thus creating a situation in which the

sum total of these contact surfaces will still allow a favourable force distribution even in the presence of inappropriate loading patterns that would otherwise give rise to osteolysis around individual disks and loss of individual implants due to isolation-related overloading. It is still possible to use this multi-implant strategy with immediate loading. The larger number of implants and load-transmitting surfaces will increase the direct bone-preserving effect of the implant surfaces relative to the effect of macrotrajectories.

BOI-based treatment with strategic implant positioning only is contra-indicated in the presence of permanent dysfunction. Consider that a resting osseous system may be present at the outset of therapy in which the preoperative trajectorial bone orientation may no longer be wholly in line with the functional pattern. Any increase of the BMU frequency and artificial stimulation of remodelling in this situation as triggered by an implantation procedure would abruptly induce reorientation of the bone structures, particularly if the masticatory function is not bilaterally balanced, which give rise to substantial morphological alterations. In masticatory systems that are not bilaterally balanced, it is considerably harder to tell in advance which bone areas will remain stable and sufficiently mineralized over the years.

The patient should be informed, that the treatment outcome is less predictable in the presence of permanent dysfunctions. These patients, however, have a strong desire to gain implant therapy, because their impaired oral function is a tremendous problem for them. Since aesthetic surgery and especially reduction of the masseter muscle are becoming more popular today, we must take the possibility into consideration that patients have had parts of their chewing muscles removed. This will affect BOI implant treatment in some respects:

Due to severe changes in the masticatory forces, severe remodelling may take place because the equilibrium between forces and bone mass was changed. The question of whether the degree of postoperative mineralization of the bone matrix will ever reach preoperative values must also be raised. This question is directly related to the stability of the contact situation and the stability of the masticatory plane.

The chewing forces will not be the same on both sides because the muscles will usually not be removed absolutely symmetrically. Also force vectors will have changed. For this reason patients with this preoperative status should be considered as having a (hidden) non-correctable dysfunction.

Strategic implant placement is not recommended in these cases and the patients must be informed that

the dissection of chewing muscles may complicate implant treatment.

6.7

Storage Requirements

Dentists who rarely use implants, or who are just beginning to use them, tend to acquire all necessary instruments while failing to keep a well-assorted selection of implants in stock. This kind of approach is clearly not recommended with BOI implants. For one thing, it is difficult to acquire the correct implant types for a specific patient without having expensive CT scans performed beforehand. For another, the dentist will not be able to offer implantation procedures immediately (e.g. after extracting teeth) unless he keeps at least a small selection of implants in stock. This is clearly not an ideal situation because these single-step procedures are very favourable both for clinical and psychological reasons. The extraction socket will allow effective suppuration from the implant site, and the patient will be spared the frustration of tooth loss if the destructive step of tooth extraction is immediately followed by the constructive step of inserting, if not a new tooth, then at least the basis for a fixed restoration.

As a minimum requirement, the dentist should always have G5–G7 implants with diameters of 9–12 mm handy. Triple-disk G3–G7 implants (with or without a fixed head) as well as EDAAS 10/20 and EDADS 12/17 designs are frequently called for as well. Also, BOI users like to additionally insert ED(S) 7 and 9 G8 implants for better stabilization (as an optional fifth implant to support complete-arch restorations). EDAS and EDADS offer great flexibility in width because they can be bent, or they can be inserted transversely or diagonally. The EDAS 9/14 G7 design is certainly the most commonly used single-disk implant at present, along with rounded or angular designs with a diameter of 12 mm.

When double-disk implants are considered appropriate, they should be selected in such a way that the basal disk is as large as possible. Basal diameters of at least 12 mm can be commonly used in the maxilla, while diameters of 9 or 10 mm are usually appropriate in the mandible. We do not use any multi-disk implants distally of the mandibular nerve so that the implant-restoration structure does not become unduly rigid.

BOI implants are extremely flexible thanks to the option of using oblique insertion pathways. It is therefore not necessary to perform a comprehensive diagnostic work-up as required for crestal implants in many situations.

6.8

Systemic Health Diagnosis

The systemic diagnostic requirements for restorative treatments based on BOI implants are essentially the same as in crestal implantology. We use the following standardized questionnaire, to be filled in by the general practitioner, to learn more about our patients' medical histories. In some situations it may be necessary to get in touch directly to enquire about the presence of allergies and the use of any anticoagulant drugs, antibiotics or other medications.

The issue of contraindications to dental implant therapy has been discussed for decades. Some of these discussions may have been prompted by attempts to blame specific implant losses on the patients themselves rather than to the implantologists or restorative dentists. Today, more and more experts agree that a great many of the factors that used to be regarded as absolute contra-indications to implant treatment do not really affect the treatment outcome and long-term stability of implants. On the contrary:

- We have successfully treated patients with diabetes mellitus, HIV or liver disease over all these years. BOI implants have also yielded excellent results in smokers. We have also treated many patients who quit smoking for good to protect their implant-supported bridges.
- Although this observation remains to be verified in formal studies, the prognosis of BOI implants does not seem to differ in any way between smokers and non-smokers once soft-tissue healing has been completed.
- Patients with well-controlled diabetes mellitus tend to be good candidates for implant treatment because of their greater health awareness.
- The risk of complications tends to be higher in patients with a relatively uncritical and negligent attitude towards life because they are less likely to comply with the treatment requirements than are patients with concomitant diseases (see Chapter 26, section 4).
- Any risk factors have to be discussed with all frankness. After all, the ultimate decision whether or not implant therapy should be performed must be taken not by the dentist but by the patient.
- We have developed a critical attitude towards patients with a substantial drinking habit, although the use of alcohol is extremely widespread these days. The same reservations apply to smokers, of course, since any of these habits are generally indicative of self-negligent behaviour.

Some concomitant diseases will affect not so much the restorative and maintenance phases of BOI therapy as the implantation procedure itself. Absolute contraindications would include chemotherapy, immunosuppressive therapy, leucopenia, and malignant haematopoietic diseases. No claim to completeness is being made here. In patients who have survived any of these (related) diseases, the option of inserting BOI implants after all needs to be discussed with the treating physicians with regard to the individual's circumstances, probability of recurrent disease and life expectancy. If implant therapy is considered appropriate in patients with a limited life expectancy, BOI-based approaches with immediate loading are certainly more appropriate than any crestal implantological protocols, which will normally involve prolonged healing periods.

Another issue that needs to be considered very carefully is whether the implant procedure should be performed under general anaesthesia, sedation, nitrous oxide analgesia or local anaesthesia. Continuous application of oxygen (e.g. 3 l/min through a nasal probe) is strongly recommended in patients with impaired respiratory function.

6.9

Structural History of the Implant Site

The local history of the implant site, including the self-trabeculating bone properties, must be carefully explored (see Chapter 9, section 1.6). The trajectorial orientation of the cortical bone structures will remain unaffected by any teeth extracted or any crestal implants lost shortly before the BOI procedure. If any BOI implants were lost, however, there is a chance of o-areas having formed that are not going to be stable anchorage points for immediately loaded implants (see Fig. 9.6). In this situation, it is recommended allow the implants to heal without loading for a period of 6 weeks. Alternatively, it is also possible to insert the new BOI implant at a different site or to reinsert a design with a greater number of disks than the previous implant.

6.10

Diagnosis of Speech and Hearing Function

Whenever extensive restorations are planned, an unequivocal diagnosis should be obtained prior to the very first treatment steps how the patient's speech function has developed over the years and to what extent the hearing function is intact as well. Note that many patients will claim that they have no problems with hearing in general. Nevertheless, many older patients will be able to hear enough

[Letterhead of dental office]

Patient name: _____

Date: _____

Dear Dr. _____

We are planning/considering dental treatment using enossal implants for the above patient. In order to be able to prognosticate the treatment outcome and to take any special measures that need to be taken before surgery, we need to know a few facts about your patients. We would therefore like to ask you to answer the following questions/perform the following examinations:

(Please circle as appropriate and elaborate where needed)

Does the patient suffer from any non-compensated disorders of haematopoiesis or the endocrinal system?	Yes	No
Does the patient suffer from any cardiovascular disease that is resistant to therapy?	Yes	No
Does the patient suffer from any malignancies with a negative or infaust prognosis?	Yes	No
Does the patient suffer from any rheumatoid disease?	Yes	No
Is the patient permanently immunocompromised (HIV, immunosuppression)?	Yes	No
Does the patient suffer from any psychopathological disorders that affect his or her personality?	Yes	No
Does the patient suffer from any other general diseases or focal infections?	Yes	No
Does the patient have any allergies?	Yes	No
Does the patient suffer from any substitutable disorders?	Yes	No
Does the patient suffer from any diseases of the bones or bone metabolism?	Yes	No
Does the patient have a history of disorders of the upper nasal tract, especially the nasal sinuses?	Yes	No

Comments:

Date: Physician's signature and office seal:

If there are any points that merit or require discussion, please do not hesitate to call me.

Best regards,

[Signature of implantologist]

for everyday purposes, but their hearing will not be equally good at all frequencies. For them, S-, F-, TH- and SH-sounds will often be in the non-audible frequency region, which is why they may have difficulties controlling these sounds – sounds that are of particular importance for clear speech.

Only a patient who hears well is in a position to work actively on any phonetic problems that will inevitably arise in any extensive restorative treatment. A great many patients do not even notice that their speech is impaired because they cannot hear themselves properly. Instead, they are continuously reminded by others that they have a problem. Even logopaedic therapy will fail in patients unable to hear themselves. Once again, these patients do not have a problem speaking, but they are admonished by outsiders to change their behaviour without ever having a chance to control

their phonetic performance via the regular auditory feedback mechanisms.

In patients with good hearing capacity, any phonetic problems induced by restorative treatment can be expected to resolve in a matter of weeks or months. During that period, the phonetic performance will be better in the mornings than in the evenings. The patient should be informed of these developments before the treatment is started.

The circadian variability of phonetic performance comes from the fact that the patient has to make a conscious effort to control speech until new engrams have formed that will take care of this task by unconscious motor responses. As conscious control is much more exhausting than engram-driven control, the rising level of fatigue towards the end of the day will allow the old engrams to regain control. These are not optimized for the new

intraoral situation, thereby causing the phonetic performance to deteriorate.

Moreover, many patients have a hard time tracking down the source of their phonetic problem. While they will always tend to implicate the length or position of their anterior teeth, these parameters will not necessarily be the true cause. In our experience, excessively medially positioned premolars and molars are just as commonly involved in the causation of phonetic problems. These teeth will deflect the tongue during its forward movements (usually in a vertical direction), which may either cause phonetic problems, or the patient may vaguely complain of discomfort without being able to pin the symptom down. It is by no means a given that these problems can be eliminated by moving the dental arches to their preoperative locations when the

dentures were still in place. After all, the problems associated with the tongue and other soft-tissue structures may be purely due to the substantial changes in masticatory function since the time the denture was worn. For example, the mandible may relapse far into rest position once its occlusal height was re-established and an anterior chewing pattern has been abandoned, thereby creating a situation that the patient will initially experience as limiting to the soft-tissue structures (notably the tongue and floor of the mouth). The conditions for any kind of restorative therapy in which the spatial relations of the tongue and other soft-tissue structures needs to be modified, are particularly unfavourable in patients exhibiting preoperatively an anterior chewing pattern combined with an advanced or deviated position of the mandible.

Treatment Planning

S. Ihde and T. Maier

Thanks to the technique of basal osseointegration, we are today in a position to treat 95% of completely or partially edentulous patients with fixed restorations. This goal can only be achieved if a number of rules are observed with regard to where the implants should be placed and when and how they should be combined with residual teeth. Most importantly, the implantologist must understand the functional requirements of the treatment and perform occlusal adjustments in a timely manner.

There are currently two distinct philosophies of how BOI implants should be applied. While they are both clinically successful, they do have their specific advantages and disadvantages. The treatment philosophy advocated by Ihde, Haas and Spahn relies on only four implants per jaw, inserted at strategic positions. This approach does not impede flexion of the bone structures between the implants. In this way, a bone-implant restoration with adapted flexion is created.

The other treatment philosophy, advocated by Scortecchi, Heuckmann and Maier, aims to create a rigid implant-restoration system by inserting a maximum number of implants. As these systems are more rigid than the bone itself, the force-transmitting surfaces cannot become seamlessly integrated in their entirety at a high degree of mineralization.

7.1

Scope of Therapy

Strategic implant positioning is the least traumatic approach conceivable, and it optimally preserves the flexural properties of the jaw. Its main shortcoming is that a reliable configuration of forces can only be obtained if the baseline situation is correctly analysed and if the outcome is closely monitored over the following 12–24 months, until the phase of bone healing, remineralization and functional optimization is completed.

Implantologists commonly see patients who are aware that they have a problem with a partial denture and who want treatment to be confined to that specific area. In this situation, it will first be necessary to assess whether such local treatment is a

good idea. The unilateral tooth loss may, for instance, have been caused by excessive loading related to an unbalanced functional pattern. However, unilateral chewing will not resolve spontaneously if most of the other masticatory surfaces in the mandible are malpositioned or if an unsymmetrical AFMP angle is present because the residual cusps generate an unfavourable guidance. There was a time when we were inclined to oblige with requests to perform such local treatment. Today our preferred approach is to readjust the masticatory function at large and to decline treatment if an understanding is not reached. Readjustment requires early implant procedures for its fixed foundation.

Treatment decisions in favour of strategically placed implants to support a complete fixed bridge can be made more readily if the following conditions are met:

- The skeletal midlines of the maxilla and mandible coincide (clinical examination and/or OPG).
- The clinically observed AFMP angles are similar on tooth-guided lateral movement to the left and right.
- The path covered during lateral movements is about the same in both directions.
- The mouth opens with a straight movement.

If there are any functional obstacles to achieving a balanced situation, the implantologist must consider inserting a greater number of implants (using multi-disk designs), thus abandoning the concept of strategic positioning.

Chapter 10 will include a detailed discussion of functional aspects and their impact on therapy and bone maintenance.

7.2

Number of Implants for Complete Bridges

Minimizing the number of implants by strategic positioning is a very successful approach, but maximizing the number of implants has its advantages too. A detailed discussion of the pros and cons follows.

7.2.1 Maxillary Restorations

The positions of the canines and second molars are used as strategic implant locations both in the mandible and in the maxilla. In our experience, if implants of adequate size and stability can be inserted at these sites, there will usually be no need for any additional implants. In fact, only one additional implant placed in the nasal spine area may create a hypomochlion situation, making the prosthetic structure tilt around that point. Bridges that are supported by implants only always carry a risk of asymmetrical intrusion if a different number of implants or load-transmitting disks were inserted on both sides of the jaw. The canine position usually offers enough space to insert a single-disk implant with a high G value and a disk diameter of at least 9 mm. Alternatively, triple-disk implants with a diameter of 7 mm, or with a larger diameter at the basal disk, are an option as well. If a substantial bone volume is available, double-disk implants with a maximum disk-to-disk interval can be used. These designs are today available with a basal disk diameter of 12, 14 or 15 mm.

EDAS implants with a basal surface area of 9×12, 9×14 or 10×14 mm can normally be used for the distal abutment at the position of the second molar. Additional use of a pterygoid screw can enhance the stability of the implant-restoration system.

If adequate support for the bridge cannot be created at the canine positions, the dentist should consider establishing an implant-restoration system based on a large number of implants (multi-implant concept). This technique has been used for many years by implantologists like Linkow, Grafelmann, Bauer, Brinkmann, Heinrich or Scortecchi. It also involves the use of numerous different implant designs (diameters, lengths) and requires comprehensive training in implantology and a well assorted stock of implants in the office. In addition, it requires

excellent three-dimensional thinking. Multi-implant treatments are expensive and time-consuming, but they offer a very good prognosis.

The degree of resorption and bone quality varies widely in the maxilla. In situations where bone conditions have remained stable over an extended period of time, it is sometimes possible to identify function-related patterns. Usually, the bone structure is narrow but relatively high in the anterior segment, flat in the subantral portion of the posterior segment, and once again rather voluminous as well as soft in the tuberosity area. The muscle attachment areas of the lateral pterygoid muscle are usually well mineralized. These differences require the use of a wide range of implant types to take advantage of the native multicortical bone structures while avoiding any more extensive grafting or augmentation procedures. Anyway, it would not be possible to obtain an adequate primary stability of the implant based on transplanted or augmented bone, since these structures cannot possibly mineralize to the required extent in such a short time. The compensation that surface effects can provide for missing macrotrajectories is very limited. Note also that surgically treated areas remain undermineralized for a long time.

We suspect that all currently known surface types are rather similar in quality, with the exception of three-dimensional matrix surfaces, which allow perfusion of the bone from two sides (Osseopore implants). After all, the main disadvantage of enossal surfaces is the impaired blood supply and drainage.

According to Misch and Judy, the anterior maxilla should be equipped with as many primarily stable implants as possible to compensate for the initial weakness of the distal segments. It is irrelevant which implant designs are combined to achieve the goal. What matters is that the bone volume is ingeniously and adequately utilized. Any residual teeth in the anterior segment can be helpful as well.

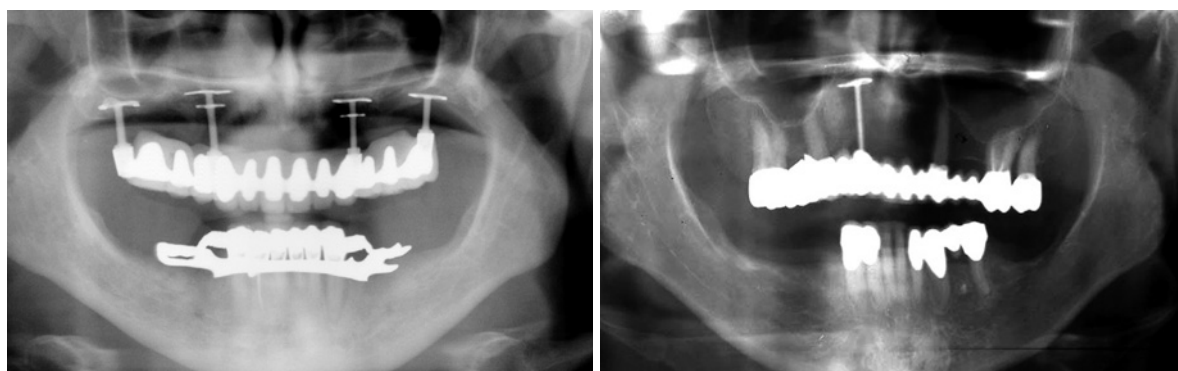


Fig. 7.1. **a** Maxillary restoration supported by strategically positioned abutments. **b** In many cases, all it takes to obtain strategic abutments for durable maxillary restorations is to combine a single BOI implant with residual natural teeth



Fig. 7.2. Maxillary restoration supported by multiple implants. The distal abutments consist of tuberosity and pterygoid screws, while BOI implants were used in the anterior segment in accordance with the available bone width. The BOI implant at 13 was vestibularly folded and adapted to the vestibular surface of the maxilla

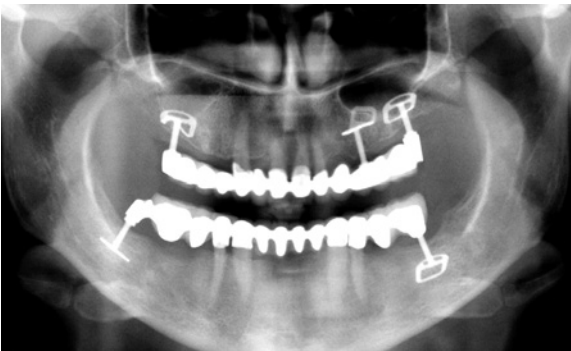


Fig. 7.3. Canines can offer very good support. They can be used alone or in combination with the first premolar

In situations of advanced resorption, it is no longer possible to differentiate between basal and crestal implantation. The important part is to utilize the cortical bone.

7.2.2

Mandibular Restorations

Since the mandible may be subject to heavy torsion, a multi-implant strategy would overly reduce the elasticity of that bone. For this reason, we generally use four to six implants, with one distal implant on each side only. Stable canines can be used instead of an implant.

Today we tend to use no BOI implants with more than one disk in the distal mandible and prefer to put no implants at the premolar positions to ensure that the elasticity of the mandible is not overly reduced and that no high point is created in the middle of the horizontal part of this bone. Triple- and double-disk BOI implants can be used to good effect along the anterior block of the mandible.

In the maxilla, BOI implants may be combined with natural abutments in virtually any combination, as long as the teeth are stable enough to offer long-term resistance to the forces acting on it. When considering a tooth as part of a larger bridge, it should be considered that overall masticatory forces will increase.

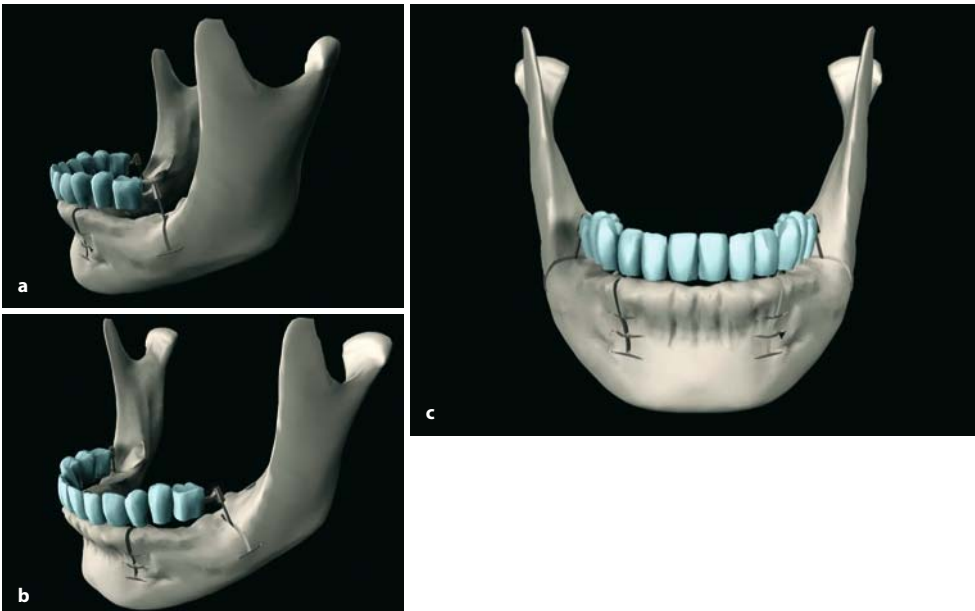


Fig. 7.4a–c. These schematic drawings illustrate the correct implant positions for strategic implant placement in the mandible

7.3

Which Jaw Should be Restored First?

Concerning the issue which jaw should be restored first, we have developed the following approach in our clinic: if therapeutic modifications are needed in both jaws, the mandible should be treated first if possible. There are several reasons:

- Complete dentures are not retained nearly as well in the mandible as in the maxilla. Therefore, the need to provide relief is greater in the mandible.
- In many cases, additional implant treatment in the maxilla turns out to be redundant once a fixed restoration has been inserted in the mandible.
- The morphological changes in the mandible are often substantial, particularly in the wake of adjustments performed to re-establish a normal masticatory pattern. Simultaneous placement of implants in the maxilla and mandible carries a high risk of overloading the newly inserted implants in the maxilla. Relative elevation of the distal implants is especially liable to inflict damage to maxilla. Conditions are more favourable once the functional adaptation after implant placement in the mandible have been largely completed.

Similar results were reported by Lindquist and Carlsson (1982), who observed that the ability to eat eight out of ten types of foods that the patients had previously been unable to eat was restored after inserting a mandibular restoration supported by enossal implants. Chewing function was significantly improved once these restorations were in place. In patients on a limited budget, a cost-benefit analysis will therefore definitely argue in favour of providing an implant-based solution in the mandible rather than the maxilla. This strategy will be effective in the majority of patients and will often render additional treatment of the maxilla redundant. According to Lindquist and Carlsson, implant treatment of the maxilla is only necessary in specific cases. We feel that this view needs to be put into perspective, as considerable progress has been made with implant treatment in the maxilla since 1982. With today's BOI technology, implant-supported fixed restorations have become just as affordable, successful and simple to realize in the maxilla as they have been in the mandible all along.

Treating the mandible first makes sense from a functional viewpoint as well. Tallgren et al. (1986) demonstrated that the changes in masticatory function brought about by inserting immediate dentures in the mandible can be reduced if a fixed dentition is at least partially present in the mandible. This conclusion is quite plausible, considering that better muscle orientation is achieved during chewing

if reliably positioned teeth are present in at least one jaw.

If a complete denture is present in the maxilla, the necessary elevation of the occlusal plane towards Camper's plane can be performed more readily than in the presence of a fixed restoration or of elongated natural teeth. In spite of that, the occlusal plane should always be equalized if necessary. Trying to save money on this aspect of treatment will be counterproductive in the long term.

One also has to keep in mind the fact that the teeth in the mandible often resist imbalanced situations better than the teeth in the maxilla. If in the maxilla large bridges are present, this will sometimes lead to a situation where a patient faces a complete breakdown of the maxillary restoration and dentition with the reason for the breakdown being located in the stronger, but unbalanced and/or unfavourably designed prosthetics in the lower jaw. We strongly recommend in these cases always to treat the lower jaw first or simultaneously, because it is dangerous to rely on the patient's willingness really to treat the mandible after the problems in the (aesthetically to him/her more important) upper jaw. We have seen sad cases where the patients forgot about the agreement about treatment in the mandible, vanished from the scene (even missing regular check-ups in order not to be reminded about the agreement), and returned later with problems again in the upper jaw.

7.4

When Should the Implants be Loaded?

Obviously, there is no way for implants to remain completely "non-loaded" once they are located within the bone. The appropriate point of time at which all or part of the chewing force should be transmitted through all or some of the BOI implants onto the cortical bone will depend on the conditions present during surgery, the number of implants inserted, and the general circumstances under which mastication takes place. Since the cranial bone is permanently in a state of torsion, there can be no such thing as a "non-loaded" state of implants. We therefore maintain that it is more sensible to define the type and direction of loading via a prosthetic superstructure than to leave the bone without this well-dosed stimulus.

Part of this rationale is to insert the superstructure while excellent primary stability is present. Following this logic, prosthetic loading should take place within the 8–12 days (the sooner, the better). Due care must be exercised in deciding on this strategy, which may be contraindicated in specific cases (i.e. in surgically pre-treated areas). The other alternative would be to load the implants after 6–8 weeks when the phase of

bone healing and bone repair has been completed. The implantologist may want to select a different time if numerous abutments are present, provided that the superstructure can then be inserted in a tension-free manner. Such re-scheduling is less advisable in the maxilla than in the mandible with its considerable macrotrajectorial stresses.

Both jaws undergo extensive bone remodelling. If a large number of load-transmitting disks have been inserted, it is unlikely that individual implants are loaded to the point of creating deleterious osteolytic processes. On the downside, little bone will remain for a second treatment attempt if implants become unstable because of other factors.

Essentially, we always attempt to insert as many implants and load-transmitting surfaces in the surgical phase of treatment as are necessary to realize immediate loading. In first implantation procedures, the goal of immediate loading can be achieved almost invariably. A temporary restoration is inserted in the maxilla for 2–12 months, while the mandible can usually be treated with a definitive restoration right away. Temporary restorations may need to be replaced or adjusted inside or outside the mouth several times, particularly in the maxilla, as functional and morphological alterations are developing over the course of treatment and/or extensive chewing-related adjustments have to be performed. On occasion, it may be necessary to compensate for spontaneous repositioning of the TMJs. Such repositioning may only occur after weeks or indeed months and may proceed in a stepwise fashion, reflecting the step-by-step release of spastic contractions of the lateral pterygoid muscle. In those cases, the masticatory surfaces must be redesigned several times, also taking into consideration that the steepness of the cusps must fit the age of the patient. Any delays in readjustment may trigger a unilateral or anterior chewing pattern.

7.5 General Biomechanical Considerations in Treatment Planning

BOI implants are designed to replace natural teeth and assume their function of transmitting the incoming masticatory loads into the bone. They consist of one or several load-transmitting disks (also referred to as basal plates or rings), a threaded pin not designed for load transmission, and web bars connecting the disk(s) to the threaded pin. The disks are available in different shapes aimed at optimally adapting the integrated implants to different bone configurations. Correct choice of the dimensions of the BOI implant is required because BOI implants, unlike screw designs, always utilize

the available native bone structure to anchor the implant-restoration systems. The bone available at the beginning of the therapy is considered to be the best bone of the patient, because it is assumed to be in the areas of main trajectories under functional conditions.

Cortically anchored basal plates are an integral component of BOI implants designed to guide the masticatory forces into the enossal space. Depending on the indication, one or several disks per implant may be required, along with threaded pins that are relatively rigid or elastic. The enossal surfaces of the implant may be either roughened or smooth, depending on the task they are designed to fulfil both in the early treatment phase and in the long term.

In our experience, disks with a diameter of less than 9 mm will always constitute relatively rigid points of load transmission. Strictly speaking, these designs do not allow implant-restoration systems that truly conform to the principle of basal osseointegration. At least, the elasticity of these systems will be considerably reduced. This clinically undesirable lack of elasticity is aggravated by short threaded pins and disks that are small in diameter but thick.

In addition, the mechanical properties of the implant material are an important factor as well. BOI implants are usually made of Grade 1 (ASTM F 67), Grade 2 or Grade 3 titanium as per that ASTM standard. Some designs are also available as an extremely strong titanium-molybdenum alloy (Ti15Mo). This alloy combines the elasticity of Grade 1 titanium with a level of strength that can otherwise only be attained with Grade 4 titanium. Long-term observations with this new material are not yet available. We currently use this material in structures that have to resist great lever forces. This is frequently the case when massive skeletal discrepancies of maxillary micrognathia or mandibular prognathia have to be overcome.

The purpose of this book is to describe how implant-restoration systems can be integrated more or less isoelastically into the viscoelastic environment of the human jaw. Bone quality as defined by Misch (I–IV) only describes the present condition of the bone, which is obviously poor in edentulous situations as the bone is not trained. Therefore, this classification is largely irrelevant for anatomists and BOI implantologists alike. Measuring Hounsfield units is, in effect, totally useless if we consider that the measured parameters will change instantly once implants have been inserted.

The only interesting aspect is how the bone mechanisms responsible for recognizing, scanning, rejecting or enclosing the implant can be optimally utilized. These mechanisms are more likely to behave according to plan if an intact blood supply is available

and if osteogenic stem cells are present in large numbers even at the outset of implant treatment.

There are also situations in which more rigid designs (e.g. triple-disk implants of the “EDDD” type) are an appropriate choice. They can be used in conjunction with other BOI or, indeed, crestal implants to support more rigid implant-restoration complexes, or they can be used as single-tooth implants to replace anterior teeth or premolars in the maxilla or mandible. Bar attachments can be used to good effect on triple-disk implants as well.

Although the concept of (iso)elastic anchorage of dental implants reappears several times in the history of our profession (Breme et al. 1993), the concept was fully realized only on a few occasions. (Intramobile elements were developed and introduced by IMZ in the early days of modern crestal implantology, based on the realization that the human body was a viscoelastic system and should not be treated with rigid implants connected by rigid splinting. Other manufacturers did not follow suit, however, and today the concept is regarded as obsolete. We are told that the market “did not accept” these designs and that they are old-fashioned. More probably, other products were supported by heavier advertising and came in ahead, despite the fact that the IMZ concept as such was biomechanically flawless.)

With crestal implants, mobile incorporation of the implant body is, after all, tantamount to fibro-osseointegration, which will quickly give rise to implant loss once the fibrous area gets infected. This problem does not exist with BOI implants.

Crestal implantologists infer from this that the jawbone will grow towards implants for which primary stability has been achieved “voluntarily” and “deliberately”, as it were, to prepare the ground for functional load transmission. As will be shown further below, a substantially greater incentive for bone remodelling comes from stimulation of neighbouring osteons when force transmitting trajectories are disrupted in the process of preparing the implant bed. This mechanism has been well known also in orthopaedic surgery. The implant itself mediates stimuli only to a very small extent in the direct contact area.

The forces acting on the various bones of the skull vary widely in different cranial areas. These bones are therefore elastic and show very different degrees of mineralization depending on their exact location. These observations are most apparent in the anterior mandible. Areas characterized by lower mineralization and higher elasticity will respond to flexural forces by more extensive deformation. Introducing large (long) implant bodies in areas of this type can give rise to any one of the following scenarios:

- The elasticity of the surrounding bone may decrease to match the elasticity of the implant. In that case, other zones of high elasticity will form in that jaw instead.
- The high elasticity may remain intact, but only a small percentage of the enossal surface becomes osseointegrated.
- The high elasticity may remain intact, and a high percentage of the enossal surface becomes osseointegrated, but the bone is undermineralized, so that the various bone layers are freely mobile.

The term “extraterritorialization” of the implants has been proposed because osseointegration was regarded as a delimiting reaction – a process of “cystification”, as it were. An implant thus becomes extraterritorialized as cortical bone forms in the interface area, ultimately reducing the blood supply and exterminating any osteocytes near the implant. This reaction is also due to a disrupted oxygen and substrate supply, which eventually causes the osteocytes near the implant to become pycnotic and thus threatened by extinction.

In crestal implantology, it has been postulated that the surface available for osseointegration should be as large as possible (DGZMK, DGI, 2001) to optimize the long-term survival of the implant (Brandt 1996). This demand led to the introduction of long implants, followed by large-diameter implants. These developments ignored, however, that the mucosal penetration point of large-diameter implants is considerably larger, thus offering more space for infection. The prognosis of short implants with roughened surfaces is seriously marred by the fact that bacterial loads rise exponentially with increasing implant diameters (Knaus 2000; Müller-Herzog and Lindorf 1996). The intraosseous blood supply is presumably greatly reduced, which may even promote the development of sarcomas down the road. Some of the postulates of crestal implantology are indeed questionable. As a case in point, the prognosis of implants covered with a porous coating allowing perfusion until deep under the surface (Osseopore) becomes poorer with increasing implant lengths because the perfusion system loses its functionality in longer designs.

Longer implants placed in areas of flexion are bound to transverse various enossal layers that will change their relative positions during normal chewing function. These movements are more apparent in the mandible, but they are significant in the maxilla as well. In contrast to the specially prepared skeletized skulls used for anatomical studies, live cranial bones are characterized by relative mobility and high hydrostatic pressures. In addition, they are affected by the rhythmical movements of the craniosacral, respiratory and masticatory systems. Notably by

the active movements of mastication and facial expression, the bones are constantly kept in a state of mutual flux and intrabony torsion. Note that the intraosteonal flow of nutrients is enhanced by bone torsion.

The successful outcomes of slightly conical non-threaded implants with a spherical surface (Osseopore) demonstrate that the same degree of anchorage can also be obtained with very short designs. These implants stimulate mineralization in a radiographically demonstrable manner and are capable, according to their users, of supporting prosthetic restorations while involving rather distorted crown-implant ratios. Obviously, these implants cannot be splinted since the tensions developing through the prosthetic structure would eventually result in bone avulsion after all. The first point to consider with these implants is that they should be inserted over their entire length into a bone layer of uniform behaviour. As a result, the level of functional movements inside the bony implant bed will be relatively low. In other words, these implants will remain unaffected by any local or comprehensive movements of the cranial bones – provided, of course, that they are not used to support large-span bridges. The second point to consider is the ingenious surface structure of these implants, which initially prevents the bone from growing too deeply under the surface. The empty space just below the surface represents a confluent system of canals that enables nutrients to be supplied by way of microcirculation very much as they are supplied naturally through osteons. In other words, the surface on which the bone layer will be forming bears greater resemblance to a three-dimensional microtitre plate than to a dead implant surface. This example once again demonstrates that even minute contact surfaces will ultimately be sufficient to adequately guide masticatory loads into the bone. As a prerequisite, however, the surface contact must be located in an area that is well supplied with nutrients. With cortically anchored BOI implants, these nutrients may be derived from the periosteum or from the interior of the jaw bone. With crestal implants, it is sometimes possible to achieve this goal through ingeniously structured surfaces and carefully selected implant sites. From the points that have just been discussed, it becomes clear why the minimum lengths and surfaces that have been “scientifically” postulated for crestal implants only apply to specific implant designs. In other words, they only apply to implants with surface characteristics that are conventional or do not lend themselves to biological integration because they cannot be perfused well in one way or another.

At this point, a brief discussion of what has come to be known as “root-form implants” may be useful. This

term suggests that these designs imitate nature, as it were, by being configured and behaving like natural teeth. This view ignores, however, that those implants are totally immobile inside the jaw. In other words, they are virtually in a state of ankylosis. Ankylosis of natural teeth is undisputedly a pathological state requiring treatment unless the tooth only becomes ankylosed in its clinical desirable end position. Crestal implantologists try desperately to establish this pathological state as a treatment objective. The nonsensical term of “functional ankylosis” used in this connection is actually a perversion of the underlying concept. Osseointegration along the vertical dimension is, of course, an inherent requirement for crestal implants since they lack any horizontal components. Therefore, jaw area in which these implants are located is reduced. The longer the implant, the greater the loss of elasticity. A designation like “root-form” implants is purely formal in meaning and cannot change the fact that these designs lack essential characteristics of natural roots such as elastic suspension or functionally supported adaptation of perfusion. BOI implants, by contrast, are elastically suspended between cortical bone structures. In this way, the viscoelasticity and flexibility of the jaw area are adequately preserved. In addition, the connective tissue along the vertical implant axis does not interfere with flow perfusion. Apparently there is a need for this perfusion to be intact, which is why osseointegration takes much longer on these implant surfaces than on the basal disk segments.

The first generation of disk implants by Julliet allowed virtually no elasticity whatsoever. Although they were made from elastic Grade 1 titanium, they were just too thick to afford the required degree of isoelasticity. Even the Diskimplant designs made by Scortecchi from Grade 2 titanium were (and continue to be) only suitable for BOI-based implant-restoration systems if the disk diameter was adequate. The reason is obvious: on the one hand, small designs are not capable of reaching the cortical bone structures in all situations; on the other hand, higher grades of pure titanium are not capable of generating the state of near isoelasticity required to obtain adequate osseointegration of the load-transmitting surfaces. Having said that, implant losses are extremely rare precisely with 7G8 ED, 7G5 EDD or 7G7 EDDD designs, due to the fact that they are usually inserted in highly mineralized bone areas where elasticity is not a top priority consideration. Scortecchi demonstrated in his book that rigid implant-restoration complexes could be established very successfully by inserting a large number of rigidly designed implants in combination with screw implants.

Today's Diskos-type implants offer a balanced combination of shape, thickness and size. Their development was based on the input of experienced users, giving rise to a design that is optimized for the expected functional loads and the mobility of the human skull while ensuring that adequate osseointegration of the basal plates is achieved at all times.

7.6

Cementing Versus Screwing

There is no simple answer to the question whether superstructures should be cemented or screwed to implants. A preferred approach of crestal implantology (particularly in the maxilla) is to screw a bar attachment to the implants and use a coverdenture as prosthetic superstructure. These systems, it is argued, are better accessible for self-performed oral hygiene. The experience of thousands of patients treated with BOI implants shows that this claim is unfounded. The truth is that fixed prosthetic solutions that are both aesthetic and accessible can be provided even in the most unfavourable of situations. In our view, the predilection of crestal implantologists for screwed bar attachments really has to do with the high rate of implant loss with these designs. The true reason is that these losses can be "administrated" better under screwed bar attachment than under cemented bridges, thereby avoiding the financial risk (i.e. the laboratory costs) of having to replace the superstructure every time an implant is lost. Screw connections offering a precise fit are much more difficult to realize than cemented connections, particularly in situations where the bone morphology has changed over the course of treatment and if conditions in the try-in phase are no longer the same as in the phase of impression-taking.

Some users prefer to remove the prosthetic superstructure at regular intervals. This naturally requires the use of a screw connection. Cemented bridges are not an option in that case.

One of the reasons why screw connections are more convenient to use on rigid implants (types IDO, IDOT or ID) is because screw-retained bridges cannot develop pre-loads along their basal components. On the other hand, internal-thread systems are associated with large implant heads of adequate wall thickness, which entails larger mucosal penetration points, thereby increasing the risk of infections.

Other users do not wish to remove the bridges ever again. Therefore, they have no occasion to embark on the technically demanding task of establishing a screw connection. After all, the time and money going into the fabrication of a screw-retained bridge would

suffice to fabricate two simple bridges from scratch. Anyway, a new bridge (even a simple Brosamle-type bridge) is often the better solution in the event of complications. We therefore use cemented bridges instead of screw-retained bridges whenever possible and advise our patients to spend less money on one specific restoration but to have new restorations fabricated from time to time instead. As a matter of fact, new restorations will be needed automatically as the old ones are reduced over time by the necessary occlusal adjustments.

In our practice, ED-type implants have yielded the best results. This presumably has to do with their high resistance to infections, which we attribute to the thin polished surfaces at the level where the implant penetrates the mucosa. The screw connection can virtually always be established outside of the mucosa. In this way, the connections are well accessible and self-draining.

To summarize, every approach has specific advantages and disadvantages. A panacea does not exist. Regarding the question under discussion here, the universities repeatedly switched sides every few years. It is safe to assume that these changes of heart were prompted not so much by first-hand deliberations and experience as by dependence on third-party funding at the hands of specific implant manufacturers.

7.7

Reducing Functional and Parafunctional Loads by Prosthetic Treatment

Adjusting the position of the masticatory surfaces can create a situation that helps to reduce the masticatory forces by loading the TMJ structures.

The consequences of great masticatory forces are also apparent in patients wearing dentures. Mercier and Lafontant (1979) observed more advanced cases of ridge resorption in patients characterized by small lower faces and horizontal orientation of the mandible (i.e. small gonion angle). They also mentioned that the attachments of the jaw-elevating muscles were located more anteriorly in those patients. In the patients who showed a relatively open bite, the last functional molars were located somewhat more anteriorly to the front margin of the chewing muscles participating in closing movements. Presumably, the orbicularis oris muscle is more strongly involved in chewing-related closing movements in those patients.

Taking advantage of the good integrative capacity of the distal mandible, we invariably place BOI implants in its terminal segment or under the linea obliqua (white line in the OPG). The endpoint of prosthetic function is at the position of the first

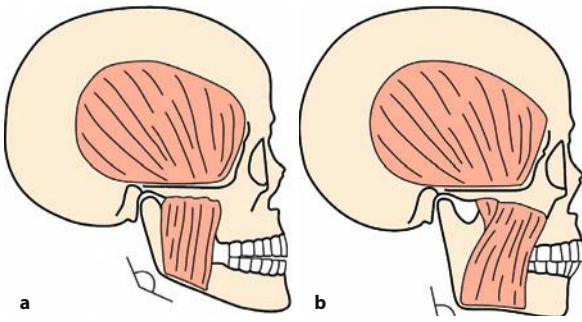


Fig. 7.5a,b. The positional relationships between the dental arches and muscles may vary. The situation on the right is characterized by a small gonion angle and a distal position of the masticatory surfaces. The TMJ is protected from high chewing loads exerted by the dental arches, which is why there is no negative feedback on excessive forces. This increases the risk of parafunction. On the left side, by contrast, the vertical muscle forces are not blocked by the dentition and fully impact the joint area. The masseter muscle has an anterior and a posterior part, and any weakness of one of these parts may lead to differences in load propagation to the joint during mastication and parafunctional activities (modified from Mercier and Lafontant 1979)



Fig. 7.6. While the distal positions were selected for the BOI implants because of their biomechanical stability, no masticatory surfaces are required distally to the first molar. The pontics are designed with a mucosal clearance, so that they cannot interfere with the crestal growth of the mandible

molar. In this way, we artificially create a situation like the one illustrated on the left side of Fig. 7.6. In the postoperative remodelling phase, the morphology of the mandible changes by bending slightly upwards towards the caudal aspect. This gives rise to premature contacts in the distal posterior segment that have to be periodically adjusted. If these adjustments are performed late or not at all, the implants in the mandible or in the opposing jaw may be affected by overload osteolysis.

7.8 Reducing Functional Loads by Drug Treatment

The chewing force needs to be reduced in the early postoperative phase to preserve initial bone contact as bone structures are being repaired. We instruct our patients to confine their diet to soft foods that are not chewed at all or can be chopped through in a single bite. Nevertheless, there are always some patients who do not grasp the meaning of “careful” and fail to understand the implications of adaptation losses. Patients with parafunctions who are aware of their problem and are found by the dentist to perform excessive biting movements as well can be prophylactically treated with drugs that reduce masticatory forces.

One option would be to reduce the activity of the entire organism by medications like oral meprobamate. Note that these patients will not be able to drive a car for the duration of treatment.

It has therefore become increasingly popular to use drugs with local activity such as botulinum toxin (Sommer and Sattler 2001; van Lindern 2000). Results based on relatively large patient samples are now also available for the treatment of bruxism by infiltration of the posterior temporalis muscle and/or the masseter muscle (Chikhani et al. 2001).

The following dosage specifications for botulinum toxin are based on the commercially available preparations Dysport or Botox. These products are packaged as a dry substance bound to human albumin that is reconstituted by the user with a sodium chloride injection (0.9%) to yield a solution. The product has to be stored in a cool place and transported in a refrigerated state. Once reconstituted, Dysport has to be used within the same day. One package contains 500 units of the dry product, which will suffice to treat up to two patients.

To minimize costs, it may be useful to schedule treatments such that the package can be shared between two patients. The preparation must not be shaken during reconstitution to avoid inactivating the active ingredient, which is not too stable.

Dysport blocks cholinergic transmission along the motor endplate by inhibiting the release of acetylcholine. Initially, the mode of action is directed at binding the extracellular receptors in a specific and saturable manner. Subsequently the toxin is internalized. The nerve endings of the motor endplate will no longer respond to neural impulses, and the neurotransmitter is not released. Presumably, the structures of the motor endplate are disintegrated by chemical action once the toxin has advanced into the cell.

Impulse transmission is restored as nerve endings and motor endplates are being re-established in the phase of regeneration, which will start around 8 weeks after the toxin was administered. While the newly formed structures are anatomically different from the previous ones, they are nevertheless fully functional. It is not recommended to use several applications in series, as the consequences of this approach have not been investigated.

7.8.1

Dosage

A dose of approximately 500 units would theoretically suffice to appreciably block the masseter or temporalis muscle. An overly low dose will reduce the duration of action because any residual muscle movements associated with subtotal inactivation will stimulate the blood supply to the point of flushing the active ingredient away. Therefore, the dose level per muscle should be in the range of 100–250. The preparation should be injected at two separate sites, preferably at the jaw angle and the adjacent parts anterior to the masseter muscle.

If the masseter muscle is blocked only, the patient will attempt to restore his or her normal masticatory force by boosting the activity of the temporalis muscle. Thus the only way to ensure that the masticatory forces are safely reduced is by inactivating both muscles in a bilateral manner. Muscle inactivation will begin within 1–3 days of injection and last for 2 weeks up to 5 months at a mean duration of 2 months. The effect is building up gradually. It begins near the injection site and will then spread throughout the muscle in a matter of 2–3 days.

Treating the temporalis and masseter muscles on both sides of the jaw will take around 400–800 units. While this dose level is far below the lethal range of 39,200–78,400 units in humans, this range refers to the systemic toxicity. Any local applications that reach the myocardium, for instance, would be life-threatening even at therapeutic doses. The drug has to be transported in a refrigerated state and carefully stored.

The solution is injected intramuscularly, preferably through an extraoral access. The force peaks of the muscle are preferred sites of application. They can be located by voluntary muscle flexing.

7.8.2

Adverse Effects

If the masseter muscle is inactivated only, the mandible will advance to the point of generating excessively strong anterior contacts. Other chewing muscles, notably the lateral pterygoid muscle, may

respond to this with diffuse pain reactions. Any swallowing-related symptoms are usually due to subjective changes in reflex mechanisms, provided that the injection was correctly performed. Salivation may also be subjectively increased. Anterior relocation of the mandible needs to be monitored and accompanied by occlusal adjustments if necessary.

Other adverse effects include paralysis of neighbouring muscles, which is usually reversible. Emergency ventilation should be available on short notice, since respiratory muscles may also become involved if the injection is not properly executed. An antidote is not available.

As the mandible may undergo anterior repositioning on losing the balancing support provided by the masseter muscle, temporary restorations inserted in this phase have to be adjusted in a timely manner to avoid excessive loading by prosthetic or masticatory forces.

We have observed many cases in which the mandible underwent significant relocation after injection of Dysport. In our view, this phenomenon is due to a process of relaxation or reorientation of the entire masticatory apparatus in which muscles spasms are resolved that have always been present but remained undetected and never resolved spontaneously.

7.8.3

Indications and Rationale

7.8.3.1

Prophylactic Administration

Generally speaking, any newly installed load-transmitting surfaces in bone-implant interfaces should be protected against shearing forces and deleterious overloads until an adequate load-resistant integration of the enossal titanium surfaces has been reached.

The focus of local muscle blockade in dental implantology is on situations where extensive clusters of chewing muscles can be readily identified by visual examination or palpation. Treatment is also indicated in patients who report having a record of nocturnal muscle activity and who exhibit advanced denture-related pressure atrophies. These patients are unable to control their masticatory forces in a voluntary manner and appear to be relatively tolerant or, for that matter, indolent with respect to oral symptoms (e.g. pressure sores).

Furthermore, treatment with botulinum toxin is also indicated in patients who evidently have a poor “sense of direction” as far as oral function is concerned. These patients tend to develop excessive habitual forces in a wide variety of chewing areas that are not directly associated with mastication itself but

are triggered in an involuntary and uncontrolled manner. In our experience, these mechanisms are most likely associated with psychological factors. Both extroverted and inhibited personality structures could be affected. Patients with eccentric parafunctions, which frequently go undetected in practice, are rendered unable to use the full force of their muscles as well.

Advanced ridge resorption involving papyraceous thin bone walls, notably in the maxilla, is another situation where the chewing forces may need to be reduced.

During sleep the mandibular position differs from the position during the day. Muscular dynamics during sleep are unique to that during voluntary clenching and exert a greater mechanical load on the balancing side temporo-mandibular joint (Minagi et al. 1988). Therefore forces exerted on the peri-implant bone cannot be controlled by the patient during the night as they can during daytime. This is another reason why in cases with a compromised bone supply (especially in the upper jaw) the application of botulinum toxin must be considered.

Patients who presumably develop great forces on closing their jaws can also be identified by remote radiographs. Möller (1966) reported that the activity of the masseter and temporalis muscles varies depending on the inclination of the mandible, characterized by increasing amplitude in an anterosuperior direction as the mandible rotates. The gonion angle is small in these cases. Findings to the effect that the masseter muscle is most active in individuals with a small gonion angle were also reported by Witt (1963). Ingervall and Thilander (1974) observed a distinct relationship between facial morphology on the one hand and muscle activity during chewing as well as maximum intercuspitation on the other. During function, the amplitudes of the masseter and temporalis muscles were higher when the jaw bases were parallel but also when the mandibular occlusal line and the Go-Gn line were parallel. Strong chewing forces were associated with smallness of the lower faces and perpendicular jaw angles. Sassouni (1969) reported that muscle forces were three to four times stronger in patients with a small vertical dimension than in patients with a relatively open bite.

Any teeth located between the muscle ends can obviously reduce the forces to be absorbed by the TMJs. Lim Kheng (2000) demonstrated in this connection that chewing forces increased when the TMJ area was anaesthetized at the time of measurement.

In situations where several of the above-mentioned factors are simultaneously present, the use of botulinum toxin should be considered all the more, especially if strategic abutments are planned.

The prophylactic use of botulinum toxin is certainly indicated in patients with severe osteoporosis who are treated with maxillary implants.

7.8.3.2

Therapeutic Application of Botulinum Toxin

Even BOI implants that have been firmly integrated for many years may suddenly become mobile. These situations are usually caused by alterations at the masticatory surfaces. We have routinely observed cases in which major areas of mastication were lost in the opposing jaw of total BOI-based bridges. Unless these masticatory surfaces are replaced in a timely manner, a unilateral chewing pattern will develop and give rise to implant mobility. The reasons for this are as follows:

- The process of comprehensive remodelling leading to the development of new load-transmitting trajectories will per se compromise the stability of the implants.
- Unilateral chewing is liable to excessively load the implants on that side of the jaw.

Implants that were well integrated the first time around have a good chance of recovering their stability as long as the decalcified matrix in the granulation tissue has not been remodelled and the situation is not exacerbated by any infections along the load-transmitting surfaces.

The treatment requirement in these situations is to eliminate the cause of excessive loading without delay. One way of achieving this may be to insert additional implants in the opposing jaw (and, of course, in the affected jaw if necessary). Anyway, the treatment must be aimed at restoring a balanced chewing function. At the same time, the chewing forces are reduced by administration of botulinum toxin. The chances of reintegration are substantially improved by this precaution. We have observed cases in which highly mobile bridges stabilized in a matter of weeks after performing these two measures.

In our view, the use of interceptors is not a viable alternative to the treatment described above. After all, these devices rely on muscle-generated stimuli focused on a small number of teeth that are designed to reduce the chewing forces by inducing pain. Implants do not have proprioceptors.

Splint therapies, TENS devices and suchlike are not helpful either. All these alternative approaches are unable to deliver the required effect, which is to relieve the implant-bone interfaces of any excessive forces whatsoever for a defined period of time (approximately 2 months).

One may be tempted to argue that treatment with botulinum toxin must be equally deleterious since the chewing forces will return to their old levels after treatment. This argument misses the point. After all,

an increase in masticatory load is appropriate and indeed necessary once the implant-bone interface has consolidated to the point of offering adequate support in order to improve bone quality in the interface area.

Note that the muscles will shorten as their activity increases with the recovery of chewing forces once the toxin is no longer effective. Therefore, the distal portions of the prosthetic superstructure, which has homogeneously settled in the intraoral space during healing, need to be extensively reduced to avoid excessive loading.

7.9

Extraction Versus Preservation of Natural Tooth Structures

Restorative dentists are routinely faced with the question of whether specific teeth should be extracted or preserved. The option of preserving teeth always warrants some scepticism. We should always remember in this context what our patients actually expect from prosthetic treatment.

Consider the following points:

- Seriously compromised teeth should not be included in the prosthetic structure unless there are good reasons to do so. Specifically, the dentist may choose to include any residual teeth in the temporary restoration to absorb the forces developing in the early phase of treatment while the masticatory pattern is being extensively reconfigured. Subsequently, these teeth can still be extracted or replaced by implants for the definitive restoration.
- Restorations that are supported by implants only while bordering on residual teeth whose prognosis is uncertain always carry the risk of incurring substantial complications if those teeth are sooner or later lost and need to be replaced after all. It is therefore better to consider extracting any such adjacent teeth right away and incorporate these locations into the restoration in the first place. This strategy has been shown to be more economical in the long run.
- The simplest solution in many cantilever situations is to incorporate anterior teeth. As will be shown in Chapter 12, inclusion of canines results in very durable restorations. Tooth-supported bridges extending from a distal to an anterior abutment are a well-established conventional prosthodontic technique. There is no reason to use a different approach for implant-supported bridges.
- Before replacing a first molar in the mandible, one should carefully assess how this approach compares to a conventional tooth-supported bridge with the second molar as abutment. While

we have scarcely observed any complications with Type 3c and Type 4 structures, it is nevertheless worth noting that the position of the first molar will rarely offer a truly strategic position for implant placement (with respect to an edentulous mandible). Therefore, if the second molar is expected to last for another 5–10 years, we would always prefer a crestal implant solution or a conventional tooth-supported bridge to a BOI-based solution. Alternatively, if the second molar has a poorer prognosis than that, we would replace it with a BOI implant either alone or in combination with a tuberopterygoid screw.

- Root canal teeth should be incorporated as abutments only if the root canal filling was successful and if the crown offers enough retention (after introducing a cast dowel core if necessary).

7.10

Temporary Restorations

Depending on the therapeutic scope and the treatment schedule, the implants may have to be fitted with a temporary bridge in order to restore the patient's chewing ability, but also to test the occlusal level, the occlusal relationships and the masticatory function. In other words, the temporary restoration is a very important element of the overall treatment plan. The phase of provisionalization may last between 2 and 9 months, in some patients it may take more than a year. Anyway, the exact duration is not a major concern as the patient is never left without fixed teeth. In the presence of excessive gap formation under the pontics, the dentist may choose to insert a temporary epithesis or to substitute a second temporary bridge.

7.11

Scope of Restorative Treatment

If the occlusal table is not equally long on both sides of the jaw, the patient will sooner or later develop a preferred chewing side. This will normally be the side where the occlusal table extends farther into the distal jaw segment. This situation may give rise to implant fracture or to undesirable asymmetries of the jaw in terms of shape and mineralization. In this process, sites that would normally lend themselves to implantation may become unstable and vice versa. Establishing functional symmetry is a matter of top priority if a reliable treatment plan is to be established. This goal may be difficult or even impossible to achieve in restorative treatments where parts of the natural teeth have to be left in an unfavourable condition.

Even if symmetrical relationships have been established, this situation is unlikely to remain stable. Rather, the cranial bones will undergo continuous morphological changes. As part of this process, the position of the masticatory surfaces will be continuously altered as well. Subtractive and/or additive occlusal adjustments are needed to reflect these changes. If they are not performed in time, the bone-implant-restoration system will tend to lapse into unilateral functional patterns with serious consequences for the preservation of the system at large.

For the implantologist, these points are in sharp contrast to the philosophy of osseointegration. It is nevertheless a false premise to think of implant-restoration systems, no matter how well they are osseointegrated, as being immobile in the context of the skull, considering that the cranial bones are themselves subject to deformation and mobile relative to each other. Implants, by contrast, do not possess the ability of natural teeth to adapt by elongation. On the other hand, changes of the horizontal bone level can frequently be identified as relative elongation (besides bacterial influences, which have a great impact particularly in crestal implants). It is therefore necessary to understand the biomechanics of the overall system and to establish reference points that go beyond the immediate vicinity of the inserted implants. This “big picture” cannot be captured by small-scale images.

The scope of restorative treatment is defined by the treatment objective, which is to establish an adequate, stable and symmetrical chewing function.

7.12

The Significance of Third Molars

As a general rule, the upper third molars are removed before BOI treatment. In rare cases, if the position and root relationships are favourable, they can be incorporated as distal abutments. Situations in which a third molar can be left “as is” are extremely rare.

Any wisdom teeth in the mandible that have no contralateral counterpart should be removed as well, even if they do not participate in mastication and do not seem to involve any problems on the face of it. The fact is that third molars will sooner or later alter the masticatory plane; if they are present unilaterally, they are consequently liable to induce biased chewing patterns (Sato 1987). We do not suspect that third molars exert any “forces” on the anterior teeth *per se*. Their presence does deflect the macrotrajectories of the jaw. The results in a prolonged phase of remodelling compared to situations where eruption-related remodelling is completed after the second molar has erupted. This

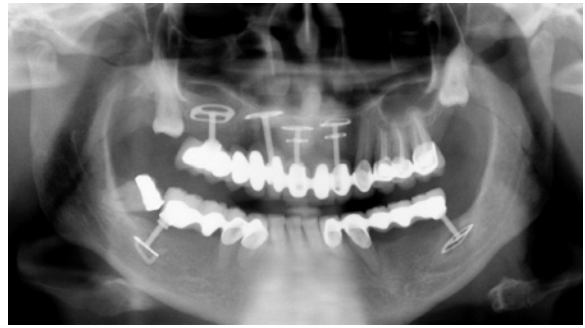


Fig. 7.7. The decision to take out 3rd molars is sometimes difficult to make, since their removal triggers extensive remodelling and large defects are found after extraction. In the case shown here, further eruption of 18 had to be expected, which also caused remodelling that led to a loss of integration of the BOI implant in Region 16. The remaining tooth also provided a considerable bacterial pool, and 3rd molars block the resorption-resistant area of the tuberosity. It is recommended either to use the 3rd molar as abutment or to extract it as part of the therapy.

prolonged remodelling will extend into a phase of life when the hormonal situation is no longer directed at building up bone volume. Enhanced remodelling in this phase of life will therefore, on balance, cause the bone volume to decrease in absolute terms. From the dentist’s perspective, the teeth are becoming increasingly crowded.

“Crowding” means that the space requirements for the clinical crowns (outside of the bone) are at variance with the bone volume surrounding the roots.

According to today’s aesthetic expectations, the crowns of the anterior dentition should ideally look like pearls arranged along a necklace. Such an arrangement is only possible with symmetrical and space-occupying roots. For this purpose, bone volume is needed in the non-supportive area between the roots, even though this bone is irrelevant for the structural integrity of the jaw. The secondary osteons enclose the vestibular and lingual aspects of the roots like belts. These belts have to be narrowed to save bone for the rounded tooth structures in the anterior segment. This process brings the roots closer to each other and gives rise to the fanned-out arrangement of the anterior crowns. This development may be arrested if the anterior teeth are retained by orthodontic treatment over many years until the phase of growth, eruption and associated remodelling has been completed. If any third molars have not been removed, this steady state will not be reached for many years to come. Delayed removal after the age range of 12–14 years has two disadvantages:

- Growth-related remodelling will last longer.
- By this time, space has already been occupied by

the third molars, and resorption of the anterior ramus with relative elongation of the horizontal branch has taken place as well.

But why does the eruption of third molars have such far-reaching implications? This question can only be addressed for each jaw separately.

- The mandibular third molars erupt in areas that are crucially important for the stability of the jaw. Tooth eruption is preceded by osteolysis in the crown region. Enzymes will additionally soften the bone structure where eruption is to take place. If the bone through which the third molar erupts is a load-bearing structure, which is the case in the mandible, this structure needs to be replaced immediately. This new bone formation usually occurs vestibularly to the crown (i.e. vestibularly to the area where the root will be located after eruption has been completed). Depending on the location of the macrotrajectories, the third molar may erupt in the centre of the ridge or in a lateral position. In young patients who require significant cortical bone structures because of high chewing forces, the macrotrajectorially oriented cortical bone structure in the area of the jaw angle will be deflected in a more lingual direction if the third molar does not erupt directly from the ridge, thereby giving rise to the well-known lingual projections along the distal ridge. In addition, third molar eruption will also influence the (vestibular versus lingual) macrotrajectories of the first and second molars.
- The dentulous horizontal branch of the mandible remains largely unchanged during growth over many years, while the ramus grows in a cranial and distal direction. The anterior segment of the ramus does not undergo resorption until the second and third molars erupt. Indeed, they would not be able to erupt otherwise. The horizontal branch of the mandible is stretched in this process. Whether adequate resorption from an anterior direction is possible depends on the strength and direction of the muscle structures. The masseter muscles in particular can be attached in such a way that adequate resorption cannot take place because the mineralization tendency of the anterior ascending ramus is more powerful than the tendency of the third molar to create osteolysis. This will give rise to situations of (partial) retention.
- In the maxilla, Camper's plane has to descend for third molars to erupt (squeezing-out effect) because there is not enough space for all three molars as long as the maxilla has a distocranial orientation. The eruption and growth tendency is counteracted by chewing forces. Third molars cannot erupt in the maxilla if very powerful chewing forces are present because the masticatory

plane will not descend far enough to create the necessary space at these dorsal sites.

- Situations where mandibular third molars are removed and replaced with implants after having been in place for many years will usually result in a relative elevation of the crestal bone level in the affected area because the area of the mandibular angle can only develop its biomechanically optimal macrotrajectorial orientation after the tooth has been removed. While those molars are present, they will keep the alveolar crest low due to the chewing forces involved. Maxillary third molars that are impacted or partially impacted do not lead to this effect because they are at the mercy of the macrotrajectories in the absence of any masticatory stimuli after their roots have developed. It is not always easy to predict whether or not the ramus will undergo anterior relocation after mandibular third molars have erupted. As a matter of fact, problems for implant treatment in that region are sometimes caused by anterior expansion of the soft-tissue structures alone.
- Orthodontists frequently argue that third molars should be extracted because they induce crowding in the anterior segment. While we do not agree with this explanation *per se*, we do see a causal relationship after all, in that the prolonged remodelling in the area of the third molar induces remodelling in the anterior segment as well, thereby reducing its volume.

As with implants, the bone-preserving effect of roots that are subjected to mechanical forces only extends slightly beyond the lamina cribrosa at best. We should also consider that the opportunity to preserve teeth in the long term even in older patients is essentially an achievement of modern dentistry. From a biomechanical viewpoint, a complete dentition can only be preserved for a lifetime at the expense of extremely straining the bone volume. If the first molars were affected by caries or had to deal with sufficiently abrasive foods early in life, there would normally be enough space for the third molars to erupt with no need for the masticatory level to descend. Considering the efforts aimed at tooth preservation and to meet aesthetic expectations, it is usually justified to extract any third molars right away.

In our experience, third molars should usually be extracted in connection with BOI treatment unless they can be incorporated into the restoration to good effect. The location of dislocated third molars in the maxilla usually coincides with the site that is required for strategic implant positioning. If removal of the third molar is associated with vestibular cortical bone loss, a two-stage surgical procedure must be considered.

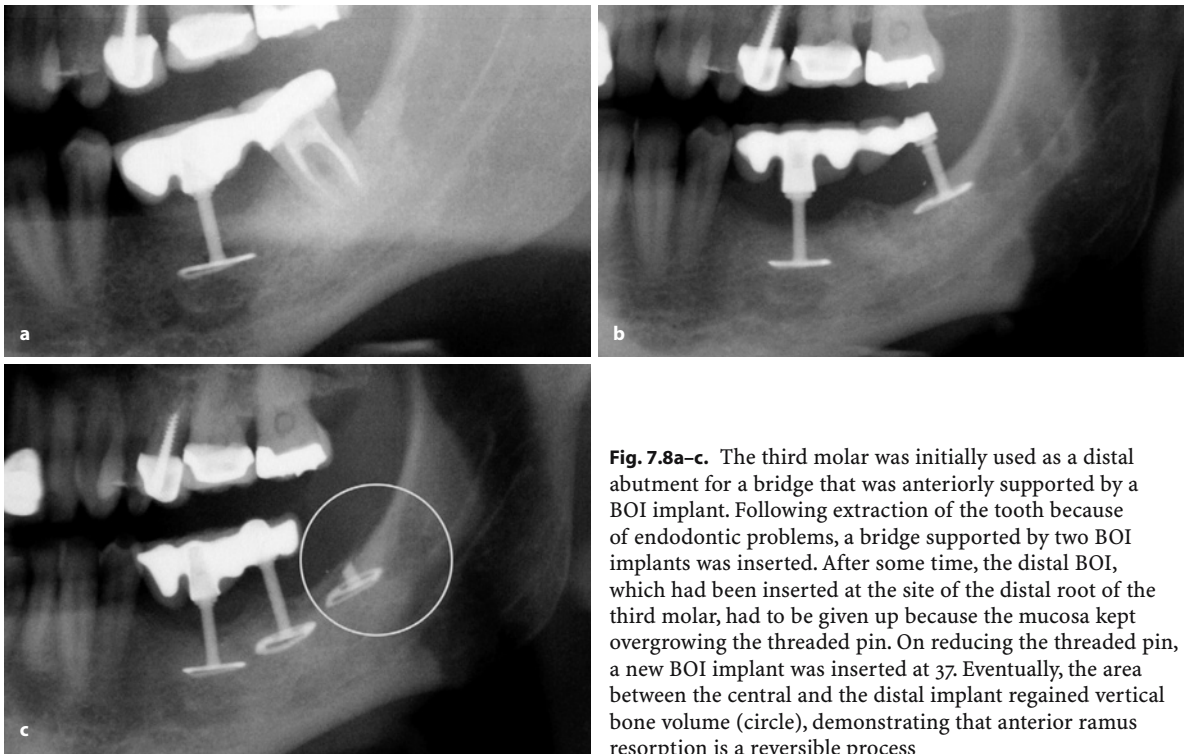


Fig. 7.8a-c. The third molar was initially used as a distal abutment for a bridge that was anteriorly supported by a BOI implant. Following extraction of the tooth because of endodontic problems, a bridge supported by two BOI implants was inserted. After some time, the distal BOI, which had been inserted at the site of the distal root of the third molar, had to be given up because the mucosa kept overgrowing the threaded pin. On reducing the threaded pin, a new BOI implant was inserted at 37. Eventually, the area between the central and the distal implant regained vertical bone volume (circle), demonstrating that anterior ramus resorption is a reversible process



Fig. 7.9. While the macrotrajectories of the mandible extend vestibularly from the ascending ramus past the teeth, the teeth are forced towards the lingual aspect. The tongue provides the necessary counterforce. Between the canines, the statically supportive macrotrajectories proceed on the lingual or vestibular aspect of the teeth at the root level. Following extraction of the teeth, they invariably move towards the lingual aspect. The necessary counterforce for the position of teeth in the dentulous anterior segment of the mandible is provided by the orbicularis oris muscle. The canine is located at the centre of the trajectories. Distally to the canine, the macrotrajectories are increasingly orientated vestibularly to the teeth. They cross this line in the root area of the premolars

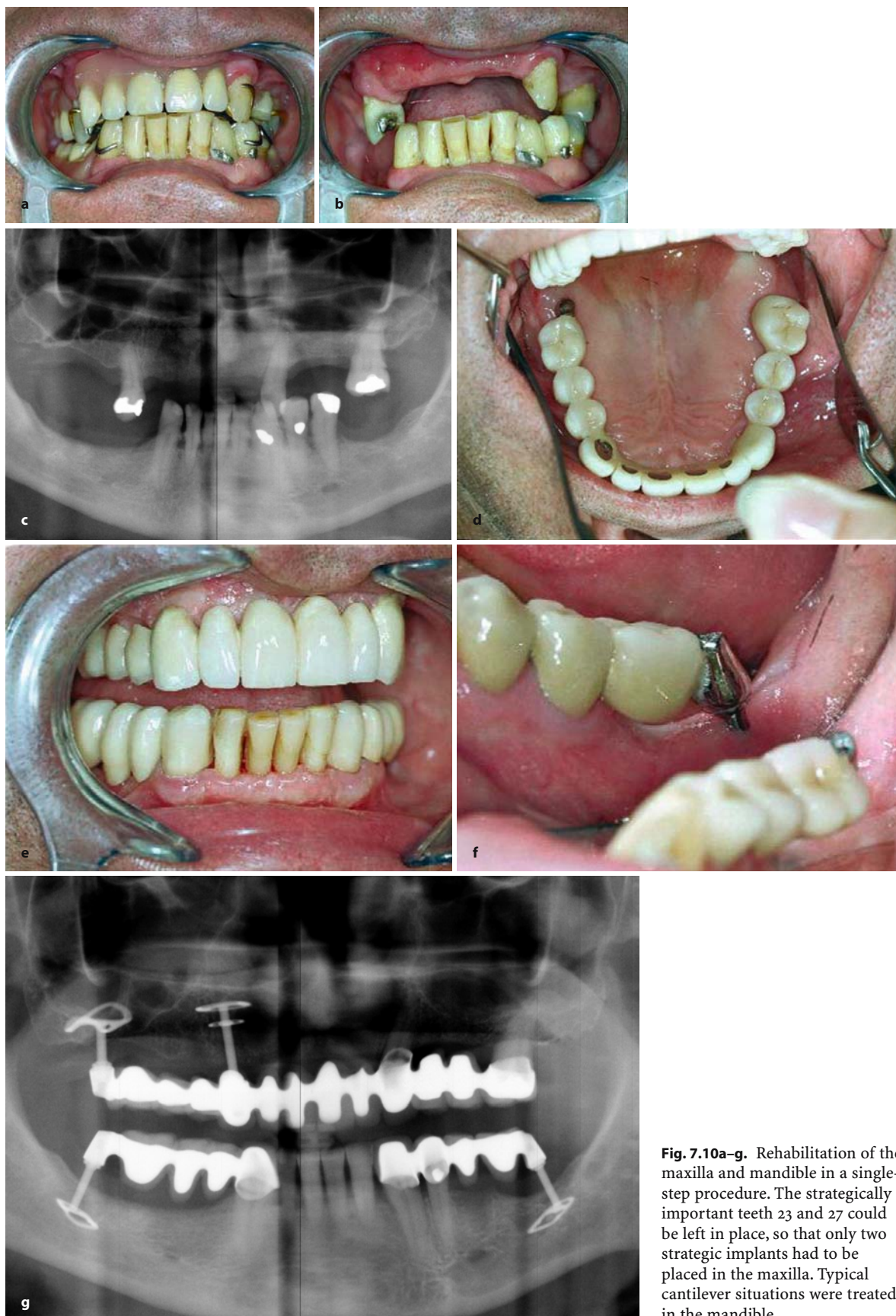


Fig. 7.10a-g. Rehabilitation of the maxilla and mandible in a single-step procedure. The strategically important teeth 23 and 27 could be left in place, so that only two strategic implants had to be placed in the maxilla. Typical cantilever situations were treated in the mandible

The prosthetic design should take into consideration that while bone resorption is centrifugal in the mandible, the macrotrajectories will relocate centripetally in a medial direction.

7.13 Summary

The path toward fixed restorations must always be based on a correct occlusal plane.

1. A sort of balanced masticatory function is more easily achievable to provide if a complete denture is present in one jaw, while the other jaw (usually the mandible, where acceptable retention of a complete denture is much more difficult to achieve) is treated with an implant-supported fixed restoration that may or may not include any natural abutments. If the opposing jaw contains a fixed restoration, measures must be taken to facilitate equilibration following BOI therapy.
2. Especially in the early phases of treatment, all contacts should be located within the support polygon marked by the greatest circumference of the base plates of the disks. This requirement must be borne in mind when designing the restoration. The technician will require clear instructions as to the size of the bridge as well as the type and location of the cusps involved. These instructions can be derived from the size of the disks on the one hand and their spatial orientation on the other. This does not apply to the anterior region, where the restoration will be designed in accordance with functional and aesthetic requirements.
3. A structured occlusal relief is required to facilitate the crushing of food.
4. The occlusal surfaces must be adequately wide. Small and narrow surfaces, as considered desirable

by crestal implantologists, will prevent a bilaterally balanced mastication pattern.

5. The design principles for the occlusal surfaces and planes in BOI-based restoration are actually more in line with complete dentures than with tooth-supported fixed restorations.
6. Any teeth in the opposing jaw must be adequately supported on an individual basis. Any teeth protruding from the occlusal plane need to be reduced.
7. In the presence of dysfunctions, it is recommended to provide a fixed restoration for the mandible while performing balancing treatment in the maxilla – using a temporary complete upper denture if necessary. This d-tour may be quite often necessary for financial reasons. In general it is always better to provide fully fixed upper and lower arches and this is, what should be recommended to the patient. Only with fixed teeth permanent balance can be established.

7.14 Final Comments

Apart from what has been said in this chapter, there is also a case against switching patients directly from fixed tooth-supported to fixed implant-supported restorations. It takes some patients the experience of wearing a denture to appreciate the high comfort of fixed teeth. If the continuity of fixed restorations is never broken, those patients may never know what life would be like without fixed teeth. This lack of appreciation may reduce the patient's compliance and willingness to fulfil his or her own contractual obligations in the long term. In this way, an interval in which the patient has to wear a removable restoration may even be advantageous.

Aspects of BOI Treatment in Periodontally Involved Cases

S. Ihde, V. Lekovic and Z. Aleksic

8.1

Introduction and Definition

This chapter discusses various BOI treatment options in patients with periodontally involved dentitions.

As has been shown and will be shown by numerous examples in this book, periodontal disease associated with excessive soft-tissue growth is a displacement process that can be traced back to changes in the direction and pressure of the blood flow at the interface between the bone and the soft tissues. It is this aspect – rather than the bacteriological aspects – that must be seen as the most salient one when reading this chapter as well as when treating periodontally involved dentitions. Bone must maintain a high level of mineralization and therefore does not tolerate any streaming or capillary blood perfusion and no high blood flow pressure. If these do occur, the «bony» properties of the bone tissue disappear, and it is replaced by tissue of various types that can summarily be designated as soft tissues.

On the other hand, bone may also be lost if its internal perfusion is lower than the extrasosseous vascular pressure:

- Excessive mineralization of, e.g. the white line, the linea obliqua, in the mandible puts the alveolar part of the bone in a precarious nutrimental position compared to the soft tissues (see Chapter 10 for details).
- If the masticatory forces are too low (which means: insufficient direct stimulation of the bone surrounding the teeth via the periodontium and insufficient flexion/activity of the jaw as a whole), the capillary flow of nutrients to the bone is inadequately supported, resulting in non-inflammatory atrophy of the bone.
- In cases with anterior chewing patterns, a high degree of mineralization of the distal mandible is caused exactly by that chewing pattern, which is why we can classify the ensuing periodontitis as strictly functional in origin, even though, of course, bacterial involvement appears as the disease progresses.
- As we can see each time a skeleton is found in the ground, the bacteria themselves are not able to

metabolize bone tissue directly. Strictly speaking, bone is the last thing that bacteria would eat voluntarily: Bone must first be converted to soft tissue (requiring a massive amount of rinsing with blood in order to remove the high concentration of ions); only then can it be invaded by bacteria and metabolized by them.

- By contrast with crestal implants, no extra-territorializing response is seen in the area of the threaded pin of BOI implants, and no cortical bone will form around this implant part initially. This means that the flow to and from the transition zone between the periosteal tissue and the bone is the same as in those areas of the jaw where no implant was positioned, i.e. the fact that an implant is present has no influence in this matter. This also explains why the soft-tissue regions around BOI implants usually show absolutely no inclination to develop periimplantitis.

The “unphysiological” (from the bacterial point of view) concentration of ions in the substrate “bone”, requires intraoral bacteria to undergo a significant metamorphosis – comparable in scope to a transition from a saltwater fish to a freshwater fish – just in order to physically approach the bone, to say nothing of metabolizing it. It may be the case that the group periodontally pathogenic bacteria is found in deep pockets exactly because they can conditionally adjust to increased ion concentrations near the bone (comparable to erythrocytes in the formative phase).

Crestal implantologists, not surprisingly, have a strong aversion against implants in periodontal involved tissue; their experience has shown them that the loss rate is considerable after implantation in infected regions. BOI implantologists experience the exact opposite: successful BOI implantation is possible even in areas of severe periodontal involvement, in one treatment step and very neatly, as long as certain fundamental principles are observed. The sites around BOI implants are extremely resistant to bacterial attacks. Thus BOI can be inserted immediately after extractions in periodontally involved areas. The bone around BOI implants usually allows integration of the implant

Table 8.1. Differences in design and clinical advantages of BOI implants

	Crestal implants	BOI implants	Clinical advantages
Threaded pin/ vertical aspect of the implant	Surface-enlarged: – Macrodesign: thread – Etching/sandblasting	Machined surface	BOI implants are less infection-prone
Load transmission	Vertical; close to or far from the mouth depending on the design	Basal, far from the mouth	Load transmission area in infection-protected regions
Structure of the load-bearing areas	Pole near the core	Broad lateral support	
Load transmission vs. infection	Load transmission areas roughly coincide with infection entry paths	Load transmission areas are removed from infection entry paths	BOI implants are less infection-prone
Nutrient and oxygen supply	Enossal supply of nutrients and transport speed are limited	Periosteal supply of nutrients can be regulated within wide margins	Overload situations can be caught and repaired by increasing the nutrient supply
Mucosal emergence point	Should be located in attached mucosa if the vertical aspect has a rough texture	May be located in either attached or unattached mucosa	Much freedom in positioning BOI implants; wounds may be closed with widely mobilized flaps after extractions
Synchronization of bone and superstructure	Restoration is synchronized with crestal/alveolar aspect of the bone due to rigid connection	Restoration is synchronized with basal aspect of the bone due to rigid connection	The fate of the alveolar bone is of no consequence for the preservation of BOI implants; large bridges synchronize basal bone areas; horizontal and vertical BOI aspects, interfaces compensate for any lack of synchronicity
Recall requirements	Frequent	Less frequent than for natural teeth	Low cost to patients during the maintenance phase; treatment success not very dependent on hygiene
Nicotine abuse	Influences the implant's chance of survival	Influences only the initial soft-tissue healing process	Smoking is no contra- indication; it only constitutes a risk during initial wound healing
Implant volume	Screw 5×13 mm: 200 mm ²	EDS 9G9: 67 mm ²	Better blood supply to the implant side. Better passage from blood through the implant site
Volume of bacteria and debris in a 2 mm pocket (assuming the layer is 0.01 mm thick)	Diameter Volume 3.75 mm 0.24 mm ³ 4.8 mm 0.30 mm ³	Diameter Volume 1.9 mm 0.12 mm ³	Thin penetration areas show less debris and significantly less bacterial attack surface. Less bacteria-related changes of blood flow in direction and quantity
Abutment diameter	3.3–6.5 mm	1.9–2.3 mm	Infection repelled “on all sides”

even though infections may be present after the extractions or as a result of periodontal involvement. Why this difference?

We believe the reason to be the implant design and the nature of the insertion process. Table 8.1 shows the differences between crestal and BOI implant types and the clinical advantages of the latter.

It should be noted that the differences are shown and organized here in terms of general principles. Certain types of crestal implants do not quite fit the pattern. Various transitional types exist:

- The bicortical screw (Oraltronics) with its very wide thread combined with smooth vertical implant surfaces is one of these exceptions. This implant is strictly basally osseointegrated even though it is inserted from crestally.
- The so-called porous-coated implants (such as Osseopore) are another of those exceptions. With their large perfusion areas located close to the implants, they offer a three-dimensional nutrient matrix to the cortical bone. By contrast with conventional screw implants, the implants can be short and still afford firm and stable anchorage. A disadvantage of this type of implant is that they are extremely prone to infection during the healing phase, since the perfusion areas, which are located in the depth of the three-dimensional structure, are rapidly colonized and offer a favourable environment for bacterial growth. Once colonized, these areas are practically impossible to sanitize. Once integrated, on the other hand, Osseopore implants are extremely durable. Longer implants with the same type of surface are less suitable, since the perfusion paths, reaching from basally to crestally, become too long and impenetrable, ultimately eliminating the advantages these implants otherwise offer.
- Crestal implants with a conical design are another peculiar type: Compression screws with a pronounced conical shape do not offer

enough contact area for deep enossal load transmission. Since the osseointegrated implant surface increases toward the crestal aspect, direct interaction between this surface and the cortical bone will also increase in quantitative (relative) terms. Compared to cylindrical screws, a smaller percentage of the load is transmitted in the basal part of the bone and a greater percentage in the crestal part with these implants. This aspect probably helps these implants promote bone preservation. Since remineralization tends to be more pronounced in the crestal area, these implants are more resistant to infection than are cylindrical screws.

There is a considerable difference between this procedure and established ideas concerning the succession of periodontal therapy and prosthodontic therapy. What is true of teeth is usually not valid for complete dentures supported by BOI implants.

Since BOI implants permit immediate insertion of fixed restorations throughout the treated region, it is not necessary to perform periodontal therapy before the extraction of teeth and the insertion of implants. This means that the excellent local blood supply of the intraoral soft tissues can be used to advantage. This means that the chances of effective postoperative infection control are greatly enhanced. With crestal implants, the implant itself blocks the most effective path of removal for intraoperatively introduced inflammatory processes and their residue, while BOI implants always allow efficient suppuration through the insertion slots.

As a rule, long-term provisional restorations will be inserted following BOI therapy, especially in the maxilla. Any gingival shrinkage or bone remodelling that does occur will be of no practical consequence. Aesthetics are restored once the soft tissues have healed – that is, at a time when the mucosal situation will have stabilized.

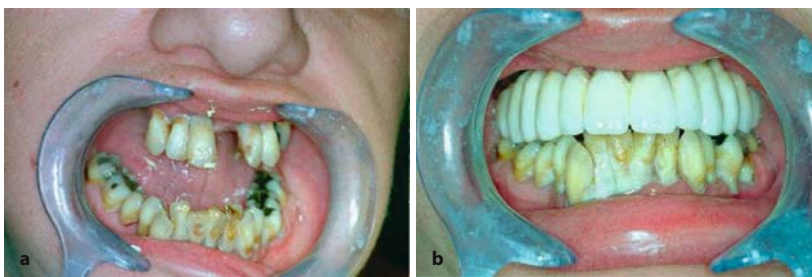


Fig. 8.1a,b. This 40-year-old patient was primarily interested in a more beautiful maxillary smile. Her mandibular teeth were barely visible when she opened her mouth normally. For this reason (and probably also for financial reasons) the maxilla was to be selectively treated. The mandibular teeth were simply cleaned (which has no long-term effect). One year postoperatively, the mandibular situation was just as desolate as before treatment. The extreme build-up of concretions with extensive bacterial plaque did not influence the positive healing process of the implants, whose threaded pins did not show any plaque or calculus

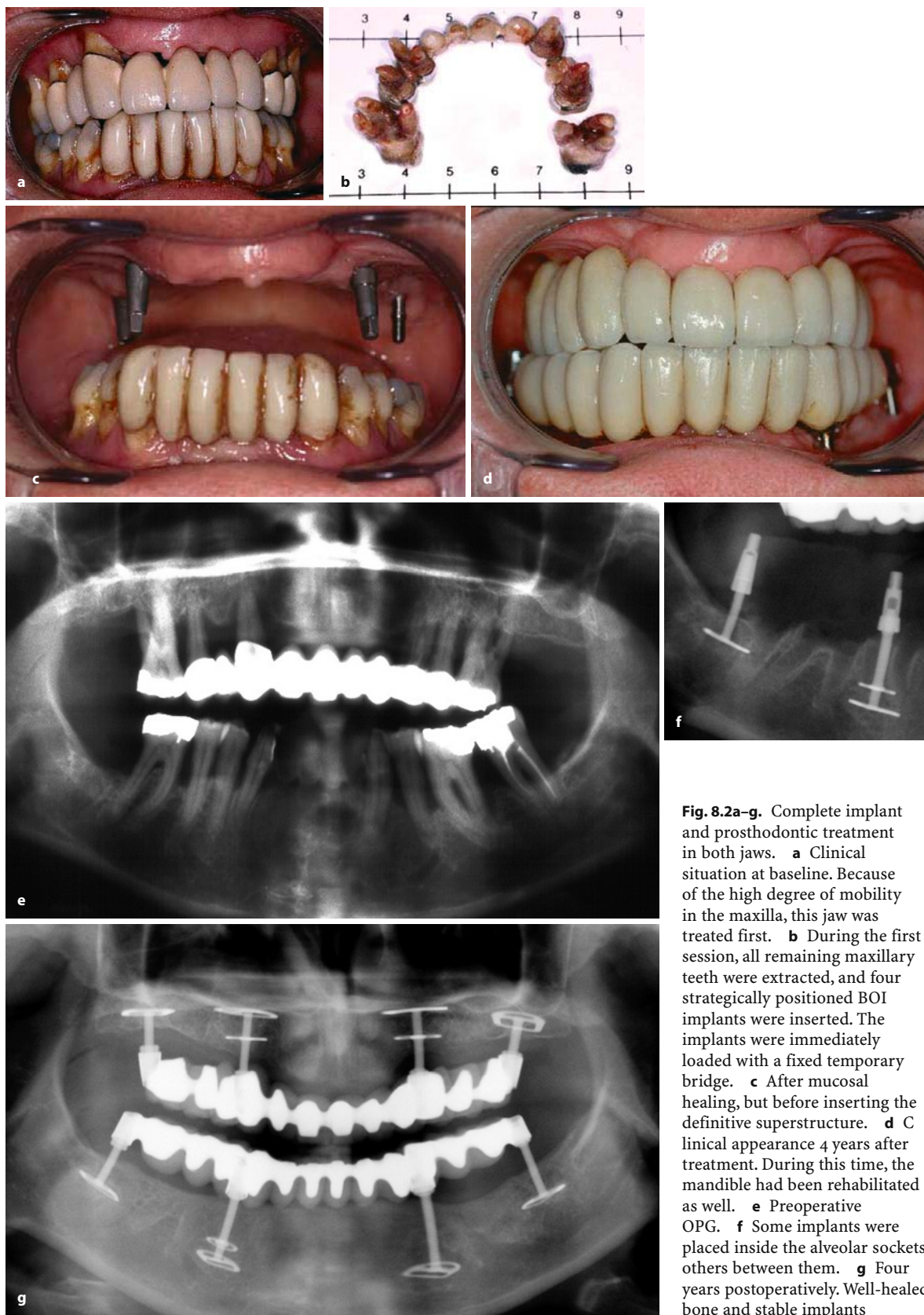


Fig. 8.2a–g. Complete implant and prosthodontic treatment in both jaws. **a** Clinical situation at baseline. Because of the high degree of mobility in the maxilla, this jaw was treated first. **b** During the first session, all remaining maxillary teeth were extracted, and four strategically positioned BOI implants were inserted. The implants were immediately loaded with a fixed temporary bridge. **c** After mucosal healing, but before inserting the definitive superstructure. **d** Clinical appearance 4 years after treatment. During this time, the mandible had been rehabilitated as well. **e** Preoperative OPG. **f** Some implants were placed inside the alveolar sockets, others between them. **g** Four years postoperatively. Well-healed bone and stable implants

8.2 Immediately Loaded BOI at Periodontally Involved Sites

A preliminary study was made of patients with up to 24 months of follow-up.

8.2.1 Introduction

In response to increasing patient demand over the last decade, the focus of implant treatment has shifted toward immediate loading of maxillary or mandibular implants.

Initial clinical studies on immediately loaded implants have demonstrated variable degrees of success for full-arch rehabilitation (Schnitmann et al. 1997). In general, the splinting of several implants by means of the superstructure results in an improved prognosis for the implants and better survival of the superstructure itself. Other studies that have focused on immediate loading of single-tooth implants in the aesthetic zone have shown greater success. However, immediate loading seems to jeopardize the success rate of crestal implant treatment.

The success rate of crestal implants seems to be higher with placement in infection-free bone tissue. Also, the level of bacterial contamination in the surrounding soft tissues should be as low as possible. In daily practice this means that, at periodontally involved sites, extraction will have to take place long before crestal implants can be inserted. Following tooth extraction the patient will need to accept a healing period of considerable duration, often having to wear removable dentures during this time.

8.2.2 Objectives

The purpose of the study reported here was to evaluate the survival rate of BOI implants inserted immediately after extraction of periodontally involved teeth directly into the extraction socket.

8.2.3 Materials and Methods

Thirty-one patients with severe to advanced periodontitis and a mean age of 64.7 ± 8.52 years participated in this study. All patients had been informed of the nature of the impending procedure and had signed an informed consent form. The protocol of the study consisted of immediately loading the BOI implants after extraction of the periodontally involved teeth. All implants placed at periodontally involved sites

during the observation period (2001–2002) were included in the study.

The decision to include the implants into the study was made based on clinical observation. The teeth and periodontal tissues at all sites were examined histologically to determine the exact degree of periodontal involvement.¹

A total of 56 BOI implants were placed following the extraction of 24 molars, 4 premolars, 14 canines and 1 incisor. Single-disk or double-disk models were used, taking into account the available vertical and horizontal bone volume. Bicortical or multicortical support was achieved in all cases.

8.2.4 Surgical Procedure

Premedication consisted of amoxicillin (2 g) administered 2 h before surgery. A regional and local anaesthetic (Xylocaine) was administered. A crestal incision was made to access the alveolar bone. Around the periodontally involved teeth, all soft tissues were removed and placed in a formaldehyde solution for subsequent investigation. The implant sites were prepared following standard BOI protocol, using regular high-speed cutting burs and irrigation with sterile Ringer solution (Ri-Lac, B. Braun, Melsungen, Germany). Bone volume, density and the perimeter of the dental arch determined the number of implants appropriate for achieving the prosthodontic objective. The flaps were then sutured with Size 3.0 silk sutures in their coronal position. After surgery, the patients were instructed to rinse with chlorhexidine twice a day for 15 days, starting on the first postoperative day, and then to use an ultra-soft toothbrush for another 15 days. Analgesics were administered on demand.

8.2.5 Prosthetic Protocol

An impression was taken using a transparent open impression tray, and the patient's bite was recorded. Temporary resin bridges were inserted immediately after surgery or within 48 h of the operation and monitored regularly. The average time between the insertion of the BOI implant and the insertion of the definitive superstructure was 7 days. One would have to consider, however, that the temporary restoration had already allowed full masticatory function.

¹ All histological examinations were performed at the Pathologie-Institut für bioptische Diagnostik, Professor M. Makek, Zurich, Switzerland.

8.2.6 Follow-Up

The average follow-up period was 6 months (range 4–24 months). Diagnostic radiographs were taken at baseline and at 6, 12 and 24 months. The influence of the following parameters on implant success or failure was evaluated: gender, arch, smoking and severity of complications after surgery (Figs. 8.3–8.8, Table 8.2).

8.2.7 Results

Thirty-one patients with severe to advanced periodontal disease participated in this study. The study population consists of 14 women and 17 men with a mean age of 64.7 ± 8.52 years. Thirty-nine per cent of the patients report smoking an average of 13.8 cigarettes per day. Patients received

Table 8.2. Region of BOI implant placement in the upper and the lower jaw

Region of extraction	Number of BOI implants	%	Total
12	1	1.79	56
13	5	8.93	
14	1	1.79	
15	1	1.79	
16	1	1.79	
17	5	8.93	
23	9	16.10	
24	1	1.79	
26	7	12.50	
27	5	8.93	
33	3	5.35	
34	1	1.79	
37	6	10.71	
43	2	2.58	
46	1	1.79	
47	7	12.50	

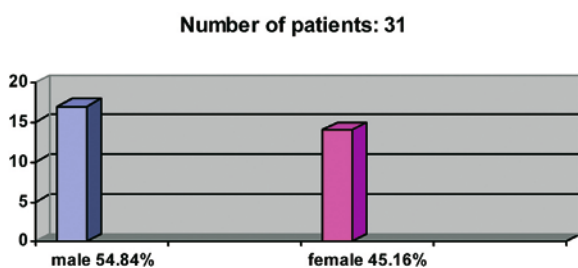


Fig. 8.3. Distribution of the patients by gender

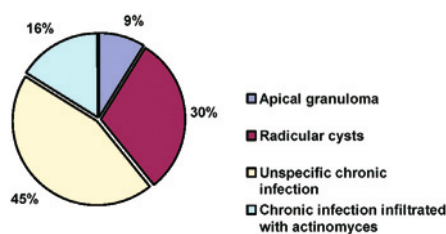


Fig. 8.6. Histological results

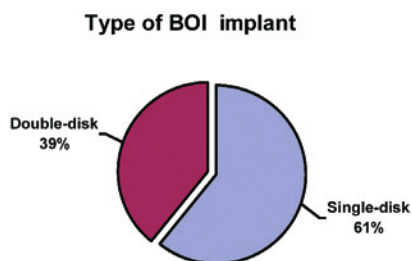


Fig. 8.4. Distribution of single-BOI and double-BOI implants

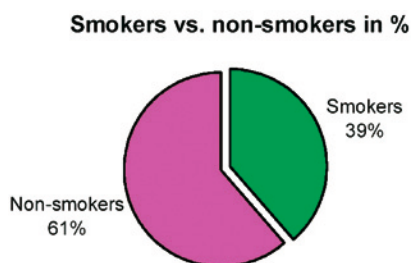


Fig. 8.5. Smoking habits

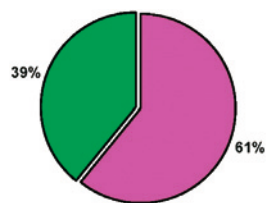


Fig. 8.7. Vital vs. non-vital teeth

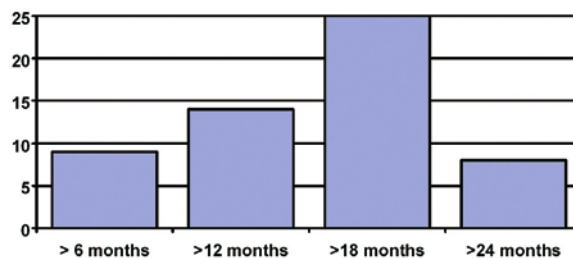


Fig. 8.8. Period of follow-up and function of the BOI implants

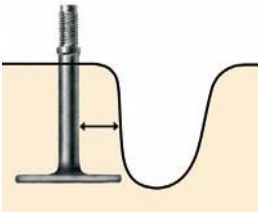


Fig. 8.9. If BOI implants are inserted next to the alveolar wall, this wall should retain a minimum thickness (A) of vertical bone that can be supplied with nutrients from a central direction. If this is not observed, there is a danger of bone necrosis in the crestal aspect of the septum thus produced



Fig. 8.10. It is not a problem to place parts of the disk inside the socket and to place the threaded pin at a distance (A) from the socket wall. Since the ring disk is perforated, the possibility of communication with the crestal aspect of the bone (with its pedicle on the insertion side) still exists

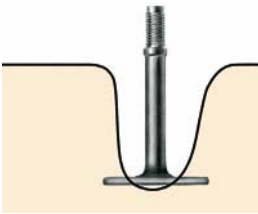


Fig. 8.11. If the implant is placed directly into the socket, the basal part of the socket must be opened with a cutting instrument in order to ensure adequate suppuration in the alveolar area. If the implant were placed any higher, infections and granulation processes could persist between the disk and the bottom of the alveolar socket. This placement is therefore definitively wrong. However, it is possible to leave two of three or one of two basal plates inside the socket, as long as one basal plate is positioned below the floor of the socket



Fig. 8.12. This drawing shows the correct placement of the basal base-plate below the border of the socket of the extracted tooth



Fig. 8.13. What was said for Fig. 8.11 and Fig. 8.12 also applies to the maxilla. It is not recommended to leave the ceiling of the socket intact as shown here. It is often here that infection and granulation accumulates over the years. Even a skeletonized basal plate would lead to an unwanted retention effect. For more information on the correct positioning of implants in the posterior maxilla, please refer to Chapter 18

a total 56 BOI implants inserted in the extraction sockets of the periodontally involved teeth. Thirty-six BOI implants were placed in the maxilla; 20 BOI implants were placed in the mandible. All cases were loaded with provisional restorations immediately after surgery. The average time between insertion of the BOI implants and the insertion of the superstructure was 7 days. No implant mobility or peri-implant radiolucencies were observed at the recall appointments. The cumulative implant survival rate was 100% at up to 24 months. During the same period, we inserted 40 BOI implants in a group of long-term edentulous patients with atrophied jawbones. Two of the implants (5%) had to be removed because of primary infection. It can be concluded from this comparison that a reliable and strong blood supply is more important for the clinical success of BOI implants than the presence or absence of bacteria.

8.3

Optimal Position of BOI Implants in the Vicinity of Extraction Sockets

See Fig 8.9 - 8.13, 16.7

8.4

Peculiarities Concerning Implants in Periodontally Involved Tissue

Implantation in periodontally involved regions has advantages and disadvantages over implantation in edentulous regions of long standing:

8.5

Summary

BOI implants are safe therapeutic adjuncts in dental implantology specifically in periodontally involved areas. The insertion process creates

Table 8.3. The advantages of implants in periodontally involved areas are balanced by disadvantages that must be considered when drafting a treatment plan

	Disadvantage	Advantage
Soft-tissue infection before operation	No sterility at the implant site	Good intrabony blood supply Good soft-tissue blood supply
Tissue healing	Large remodelling areas expected (primary stability may be lost)	Fast and efficient bony and soft-tissue healing expected
Masticatory function	New/altered chewing function/patterns must be built up	
Masticatory forces	Stronger after reconstruction: endangered equilibrium and shortening of muscles	Low forces in initial healing phase
Osseointegration	Initially porous bone with little strength	Fast remodelling and modelling

wide suppuration slots that afford drainage for the products of intraoperative and preoperative infection. The slots also prevent liquid stasis inside the bone. The excellent clinical results could also be shown in animal experiments (see Chapter 23).

The slender emergence profile makes for excellent self-cleansing properties, which means that even

patients with reduced oral hygiene can receive BOI implants. This is true both of younger patients with habitually bad oral hygiene and of older patients whose oral hygiene capabilities are reduced because of their age.

Four-Dimensional Considerations of Bone Morphology and Mechanics

Teeth and implants are nutshells in the waves of the evolving bone.

9.1 Properties of Bone Tissue in the Oral Environment

9.1.1 Cortical Bone

In this chapter, we shall explain bone properties based on a number of concepts, each illuminating one specific aspect of the osseous life cycle. All of these concepts are applicable at the same time, and they are indeed relevant for our implantological work.

Conventional thinking in crestal implantology is focused on placing an implant „correctly“ from a two- or three-dimensional viewpoint and, once this has been achieved, on adding the prosthetic superstructure in its correct position in the oral cavity. In recent years, three-dimensional planning techniques have been increasingly used for this purpose, although the crestal implants used are essentially two-dimensional.

If the interfaces of both positions do not coincide, the bony anchoring points are relocated by augmentative measures to „make“ them coincide. According to this philosophy, implants will be placed at sites that are considered appropriate from a prosthetic viewpoint, even though those sites may be characterized by bone loss. What is regarded as „appropriate“ is, incidentally, ultimately determined based on aesthetic rather than biomechanical considerations.

The fact that the first two dimensions are viewed only with respect to the bone located at the site of implantation is consistent with the present state of thinking in dental implantology. The question whether the implantation site can be expected to harbour a sufficient bone volume in the long term per se – i.e. even if no implant or other treatment was performed – is mostly irrelevant to conventional thinking. It is commonly assumed that the implant-surrounding bone is sufficiently stimulated, and thus preserved, by an „osseoprotective“ effect of the implant. In this view, any crater-style collapses are an „unavoidable result of bacterial action“. They are traditionally not attributed to mastication-related

bone remodelling, disuse atrophy, or combinations of those factors.

The most important determinant for a successful long-term outcome is, however, the consideration of the time factor inherent to bony tissues. This „fourth dimension“ will determine whether stable bone conditions will be present at the site of implantation under long-term loading and functional patterns. Time is critical, since the healing and remodelling processes inside the bone may turn out to be influenced by factors that the implantologist would not think of right away. We will therefore look at some facts and developments closely connected with everyday implant work.

9.1.1.1 Bone Healing: Remodelling

Let us first define a few terms: Primary osteons travel through woven or plexiform bone and create, as an answer to mechanical stress the first longitudinal cavities. Secondary osteons are tunnelling through

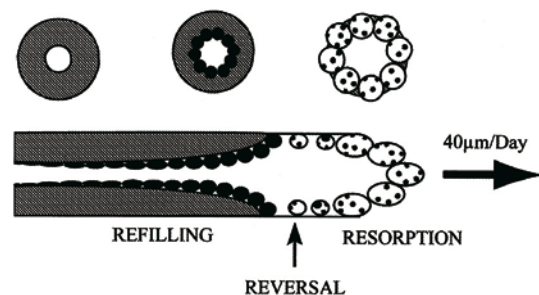


Fig. 9.1. Bone multi-cellular units (BMUs) consist of osteoclasts and osteoblasts which are combining their activities to a cutting cone that “eats” bone ahead of the osteon and deposits bone inside the newly formed cavity. The zone between cutting and deposition is called reversal zone. The tunnelling takes place at approx. 40 µm a day. On histological sections BMUs may be seen in from the side (as in the lower picture) or they may be cut as shown in the upper three sections. Newly deposited bone can be labelled with several stains, usually with tetracycline. This substance deposits in high concentration in newly mineralized bone, thus telling us which osteons or which areas of woven bone are new and refilling at the time of labelling (compare Figs. 23.32a, 23.33). (Drawing from Martin et al. 1998)

bone, which has been organized by primary osteons. Hence secondary osteons „eat“ primary osteons, while primary osteons remodel woven bone, plexiform bone or any other modelled bone materials. Intact primary osteons are only found in young individuals. The older the individual gets, the denser the denser are secondary osteons packed. Bone injury leads to remodelling, thus creating many secondary osteons.

Regardless of the type of early bone healing at the implant site, osteonal bone will have formed in due course and will increasingly mature and mineralize. The life cycle of osteons covers the following stages:

- **Activation phase.** Precursor cells develop into differentiated cells (mainly osteoclasts) within around 3 days.
- **Resorption phase.** Newly formed osteoclasts give rise to bone resorption at a speed of 40 $\mu\text{m}/\text{day}$. A “cutting cone” of cells ($\approx 300 \times 200 \mu\text{m}$ in length/width) is advancing through the bone structure, leaving behind a non-mineralized tunnel filled with fluid. The bone is becoming increasingly porous in the process. This increase in porosity is associated with higher elasticity and low mechanical fracture resistance.
- **Reversal phase.** Within several days, the osteoclasts give way to osteoblasts as the prime source of activity, which gives rise to a cylindrical space emerging between the tip of the “cutting cone” and the “tail”. The length of this space depends on the delay from bone resorption to bone formation. In finished secondary osteons, the cement line coincides with the location forming the bone surface during this reversal phase. The duration of this reversal phase in humans is around 30 days.
- **Phase of new bone formation.** Osteoblasts first appear in the periphery of the tunnel, where they start forming concentric matrix lamellae. This involves a diameter loss of about 1.2 $\mu\text{m}/\text{day}$. A central (haverian) canal needs to remain, since the osteoblasts need to be nourished. In humans, these haverian canals reach a diameter of around 40–50 μm by the end of the filling phase. Additional closure of the canals is not planned. The duration of this phase of bone formation is around 3 months.
- **Mineralization phase.** After non-mineralized matrix (“osteoid”) has been deposited, a gradual process of mineralization is started. There is a delay of around 10 days between the end of matrix formation and the beginning of mineralization. The “primary mineralization” occurring within the first few days after the process has been initiated accounts for around 60% of all mineralization. The secondary mineralization phase, which gives the bone its definitive hardness, will then take another 6–12 months, depending on the local functional requirements.
- **Dormant phase.** After the tunnelling and filling processes have been completed, a dormant phase ensues in which the osteoblasts will develop either into osteocytes or into the cells lining the haverian canal. In this phase, the cells take up their mechanical, metabolic and homeostatic function.

This cascade of processes will always develop in a uniform manner if nothing interferes with them. The term BMU (bone morphological unit) as used hereinafter is commonly used to refer to this “cutting cone”. BMU covers the whole process outlined above in its cellular and spatial entirety – i.e. the activity of osteoclasts as well as the deposition of matrix and the process of mineralization.

Once we have understood this cascade of processes, it becomes very hard to explain the “miraculous” PRP (platelet-rich plasma) treatment, which is supposed to yield benefits in a matter of days. Most of the properties commonly ascribed to PRP therapy today cannot possibly exist as stated. The marketing claims made for PRP – which have been highly effective and are supported by many dental schools – is unfounded from a scientific viewpoint. In fact, it is a telling example of how inadequately trained general practitioners and, indeed, numerous specialized periodontologists and implantologists, are duped by industry into acquiring “new clothes for the emperor”. If for no other reason, PRP cannot become effective due to platelet aggregation. Furthermore, as later chapters of this book will show, there can be no greater incentive for bone formation and maintenance than continuous function. PRP certainly is not a substitute for this either.

What does make sense, however, is to fill extraction sockets with bone-grafting materials such as Bio Oss or tricalcium phosphate – indeed, even inexpensive calcium sulphate or (tri-)calcium phosphate from the pharmacy may do. After all, these extraneous materials will prevent reorientation (i.e. straightening) of the osteons surrounding the extraction socket like a belt by their sheer physical barrier function in the initial phase of bone healing, which would otherwise cause the alveolar socket walls to collapse. It is irrelevant whether the filling material is going to be resorbed down the road, as the osteonal system will be back in a state of equilibrium in the later stages of healing (particularly in adults), so that the morphological changes of the cortical bone segments are no longer as pronounced as previously.

A more important issue for the successful outcome of implant placements concerns the direction in which the BMUs are moving through the bone.

BMUs can start and end at any cortical bone surface (periosteum, endosteum, haverian canals)

that is not covered by cartilage or excluded from remodelling for other reasons (e.g. osteoid). They usually move through the bone in longitudinal direction, without being affected by any primary or secondary osteons that may exist by that time. BMUs are capable of developing into separate prongs in completely different directions. It is assumed that the direction ultimately depends on the degree of mechanical stresses and on the bone structure. Note that the very formation of BMUs will alter the stress distribution inside the local bone as stable mineralized areas are being dissolved. Therefore, no clear line can be drawn between the cause and effect of BMU activity with regard to its direction and the distance covered. BMU can catch up any substances inside the bone during their travel. They will then unload them under the periosteum, which serves as a exchange plane. Some substances, like metal oxides, may travel with the BMUs out of the bone but they will not be able to pass the barrier of the periosteum into the blood. Instead, they will remain like a tattoo on the inside of the periosteum, which could then alter the permeability of the periosteum for other substances. Keep this in mind, when reading Chapter 9.6.

Whether the filling of tunnels is accomplished by one generation or several generations of osteoblasts is uncertain. At any rate, the filling phase does not proceed in a uniform manner but includes delays during which the osteoblasts may either remain at rest or may separate.

Osteons are supply canals with a very large surface. In non-vascularized bone areas, they take care of nutrient exchange by way of diffusion. Elastic bone structures promote the intraosteonal conveyance of nutrients by movement-related deformation. This beneficial effect is absent in more rigid bone structures; therefore, the osteons in long tubular

bones have a larger lumen than the osteons in the ribs to compensate for the lack of deformation.

With respect to BOI implants (and implants in general), this means that definitive “stable” incorporation of implants into the functional processes inside the oral cavity can be expected after 1 or 2 years at the earliest. After that time, the complication rate will decrease, as both the bone trajectories and the masticatory function will have approached a stable upper limit. A true steady state is not attainable, however, for two reasons. Firstly, the residual functional stimulus is too small (note also that long tubular bones are never completely straight) for this transformation to be overcome. Secondly, any trajectorial adaptation will give rise to muscular adjustments and vice versa, which will keep any systems of this type “oscillating” on a suboptimal level. Trajectorial adaptation is always a consequence of past functional stresses, and any functional stresses occurring at present will be reflected in bone morphology with a long delay involved.

9.1.2

Why Does BMU Activation Occur?

BMUs can be activated through various stimuli:

- BMUs may be activated to repair any cracks and microcracks inside the bone that have been caused by excessive loads (Mori and Burr 1993; Burr et al. 1985). At first, the repair work will be confined to the site of initial injury. However, since the repair mechanism involves a greater degree of porosity, which will alter the tension of the bone as a whole, situations may arise in which the porous zone propagates over a large area. Bone damage and trauma will initiate additional repair mechanisms beyond the physiological routine.



Fig. 9.2. **a** Insertion of three crestal implants replacing teeth 11, 21 and 22, followed by immediate loading with three single crowns. **b** Four months later, the osseointegrated implant replacing tooth 11 has started to migrate in a lateral vestibular direction. The vestibular cortical bone was remodelled (Atkinson et al. 1977), with the result that the implant-supported crown has undergone reorientation due to the equilibrium of forces between the tongue and upper lip. We have observed the same development of bone after immediate loading of single-tooth BOI implants. Immediately loaded single-tooth restorations using BOI implants might require overnight splinting during the remodelling period of the vestibular cortical wall, which is expected between the 3rd and 6th months postoperatively

The repaired bone shows a smaller density of secondary osteons at a higher number of BMU activations. In other words, the bone is literally “rejuvenated” in the process of remodelling – a process that may spread to extended bone areas (Atkinson et al. 1977).

- Disuse will give rise to a higher degree of porosity as well. After all, BMUs are formed at a certain frequency in an age-dependent manner. In the event of disuse, the tunnels are not refilled quickly, and bone porosity will increase, which will eventually cause the overall degree of mineralization to decrease. Unlike in bone trauma, however, where the remodelling remains largely confined to the crack area, disuse-related porosity invariably causes the bone structure to remodel in a uniform manner.
- Disregarding trauma and disuse as causative factors, BMU activation is normally an age-dependent phenomenon controlled by hormones. Activation frequencies are given in BMU activated per mm² and year. They are highest in childhood (up to 60 BMU/mm²/year) and lowest in old age (down to 1–2 BMU/mm²/year). BMU activation frequencies in rib bones have been shown to drop to their first valley at age 35, followed by a slight recovery until they drop once again later in life. The curve resembles a damped oscillation pattern (Fig. 9.4).

Another lesson that Fig. 9.4 holds for our work is that any implant treatment of patients past the age of 35 will be performed on a relatively inactive, resting osteonal system characterized by a very low degree of remodelling per se. The remodelling triggered by the implant procedure will then first induce remodelling of the surgical site, but the processes will extend throughout the entire jaw segments. The main factors determining the direction of this remodelling are force-related effects by macrotrajectories and in the interface area, but also hormonal influences as far as the direction and extent of bone remodelling

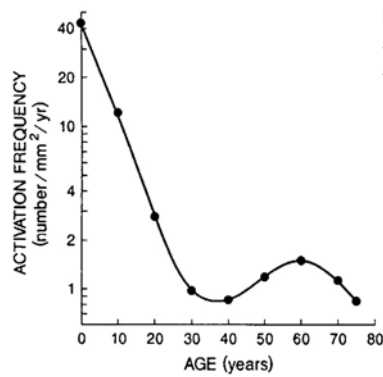


Fig. 9.4. BMU activation plotted against age (Burr et al. 1998)

are concerned. Implant treatments performed on patients under 25 years, by contrast, are not likely to trigger a lot of additional remodelling, so that the effects on macrotrajectories will be smaller as well (see also Marx and Garg 1998). Recently preoperated sites, however, show a higher BMU activation rate due to ongoing remodelling. The placement of BOI implants in these areas is still possible, but immediate loading may not be advisable.

Histological studies are an important element of implantological research. Another notable implication of Fig. 9.4 is that the implantological data obtained in animal experiments cannot be readily translated to humans, since they are usually performed on young adult animals (i.e. shortly after growth has been completed). Those young animals are thus in another “phase of bone life”, corresponding to the leftmost segment of our graph, while our dental implant patients tend to be past 40, thus showing a small degree of spontaneous BMU activity; their osteonal systems are more or less at rest.

The following conclusions can be drawn:

- Strengthening of the masticatory force will cause any cracks and microcracks in the bone around load-transmitting disk areas to increase and give rise to a greater degree of porosity associated with increased mobility of the implant. This does not necessarily mean, however, that direct contact at the implant-bone interface is lost. Porosities can accumulate to a point where perfusion inside the repair area is so strong that the degree required of mineralization can not be maintained: we call this state “overload osteolysis”. It is a reversible situation, as long as no infections affects these areas, modifies the properties of the tissue and induces granulation.
- Weakening of the masticatory force may give rise to generalized remodelling of the jawbone, which will also be accompanied by a decrease in bone mineralization. Moreover, any unloaded implants offering no functional stimulation of the surrounding bone structure will weaken the

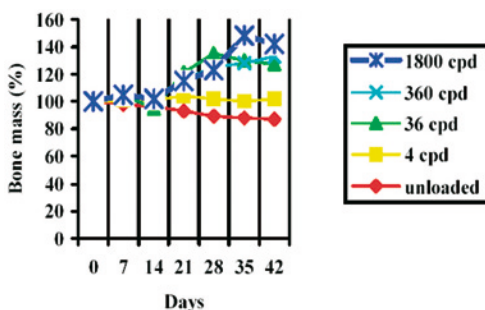


Fig. 9.3. Remodelling in response to dynamic loading (Rubin 1984). Four loading cycles per day (cpd) were sufficient to keep the bone mass constant in this experiment

bone rather than strengthen it. Thereby, any force-transmitting trajectories are likely to circumvent these implants in their development (also see the discussion of 0–1 properties at the end of this chapter).

- Any implants that do not participate in mastication may not be able to stimulate the bone at the interface in an adequate manner. Unloaded implants are thus more likely to be lost, which may take years. In that case, the demineralizing effect of bacteria in the collar area gains the upper hand and will eventually give rise to subacute chronic osteomyelitis associated with a massive decrease in mineralization.

9.1.3

Interactions Between Joints and Bone Changes

Hyaline cartilage can be neither mineralized nor processed by osteoblasts; they undergo no modelling or remodelling whatsoever. By contrast, remodelling does take place in fibrous cartilage, such as the cartilage covering the TMJs.

This difference appears logical if we consider the following facts:

- Unlike any other joint in the human body, the TMJs are two joints on both ends of the same bone articulating with the same opposing bone (= the articular fossae of both temporal bones for the purpose of this discussion).
- At the same time, both jaws are continuously subjected to morphological changes by the dentition – i.e. the formation, growth, eruption, use and loss of teeth.
- These changes are so extensive that they would disengage the high-precision fit of the hyaline

joint. Only fibrous cartilage is flexible enough to adapt accordingly. This adaptation also explains why unilateral chewing patterns give rise to radiographically manifest alterations of the TMJs. Significant flattening of the joints will, in its turn, increase the importance of muscular guidance. The ramifications of this short outline are discussed in Chapter 10.

- Being arranged in a slanted position to the sagittal plane, the TMJs are designed neither for purely lateral nor for anterior rotational movements. Rather, this type of joint excels in lateroanterior dislocation, resulting in a grinding movement that is optimized for chewing. This automatically involves a long articular pathway on the balancing side, whereas the condyle on the working side performs what is better described as a rotational movement. These functional accomplishments are outside the scope of hyaline joints.

9.1.4

Hormonal and Mechanical Influences During Growth and Aging

The age of bone samples of known topographical origin (e.g. from tibial bone) can be accurately determined based on the number of secondary osteons in any given cross-section. On this basis, the age of a patient can be pinpointed to ± 5 –7 years (Hattner and Frost 1963). Thus the number of secondary osteons gradually rises throughout life; over the years, they become increasingly overlapped and condensed (Kerley 1965). The long tubular bones have a tendency to “straighten out” in accordance with their function over time.¹ Anyone who has had an opportunity to monitor anatomical developments in the first years of life may have noted that the thighs will straighten out all of a sudden once the child is beginning to walk. In this situation, the strong flexion is not longer acceptable from a mechanical viewpoint, but this problem is solved amazingly fast in accordance with Frost’s flexural neutralization theory (FNT). The crucial mechanism is periosteal modelling along the concave bone segments.

In phases of substantial growth, the rate of bone remodelling is greater in children than in adults, which is naturally due to the hormonal situation. Due to the fast speed of growth in adolescents, the degree of mineralization may sometimes lag behind. The formation of plexiform bone as a

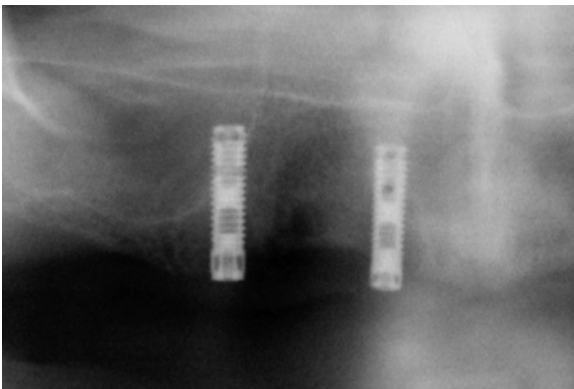


Fig. 9.5. Unloaded screw implants (featuring no surface enlargement) 8 years after insertion. Those implants could be easily removed by just “picking them up”. They were characterized by chronic inflammation after having been repeatedly covered by mucosa. The macrotrajectories avoid these implants according to the 0–1 rule, as no bone-preserving stimulus is present at the enossal implant surface

¹ However, they never attain an absolutely straight form, since the last bit of straightening requires a mechanical stimulus that is absent. The lower the residual curvature, the lower the stress facilitating the residual straightening effort, that is, the change in concavity according to Frost’s FNT theory.

temporary corsage is one of the precautions that the live bone may take against fracture as the stresses are continuously changing both in degree and in direction. Because the activity is usually decreased in adults as well, the frequency of BMU activation drops quickly. Apparently, this results in a shortage of activation which is then counteracted by a new rise in frequency.

9.1.5

Disuse Atrophy, Blood Supply and Periodontal Problems

Contrary to a widespread misconception, jawbones show resorption not because they are subjected to (denture) pressure, but because they suffer from undernourishment combined with a lack of drainage.² Pressure, as a rule, creates bone.

The observation that the vertical bone volume (particularly in the posterior segment of the mandible) rapidly decreases after insertion of a denture (Blatterfein and Payne 1985) has prompted explanations to the effect that the bone is “pushed away”. This notion of a denture-related pressure atrophy continues to be taught at dental schools and is firmly planted in dentists’ heads, despite the well-known fact that there is no relationship between the surface area of the denture base and the extent of atrophy, although such a relationship would be logical if the pressure per surface unit were a relevant factor (Suenaga et al. 1997).

Consequently, the reduction in bone volume is not due to the chewing pressure but to a combination of individual factors such as lack of intrabony blood supply in the absence of a drainage pathway from the crestal mucosa, which affects periosteal regeneration. Subsequently, the mandibular artery will be more susceptible than most other arteries to sclerosis and partial closure (Bradley 1975). This is particularly true after the teeth have been extracted. This artery is around 15 years ahead of the major carotid artery in terms of its degree of sclerosis. Therefore, the central blood supply to the mandible will be significantly reduced particularly in situations of advanced resorption (Mercier and Vinet 1983). Following tooth loss, the bone-stimulating function along the dental roots is gone, so that the alveolar jaw areas will simply succumb to disuse atrophy. The reason why the blood supply to the mandible is greatly reduced is that no more drainage pathways are present following tooth loss. While teeth are present, the bloodstream to the mandible is distributed to the

dental roots and the periodontal ligament – where great amounts of blood are needed on a continuous basis to maintain the local immune system and nourish the tissues – and is drained through the subperiosteal tissue. After the last tooth has been extracted, the bone will close in a definitive manner, and the interior of the mandible becomes congested. The last remaining drainage pathway through the mental artery is overly narrow. Even while teeth are still present, the increase in mineralization in the mandible will significantly raise the resistance to intravasal pressure of the mandibular artery in the 4th decade of life, so that the direction of the blood supply may conceivably be reversed, thus going from the periphery to the centre, in some people. In heavily resorbed mandibles (i.e. in the remaining basal segments) it is known anyway that the bulk of the blood supply is guided from the peripheral zone through the periosteum. In other words, a number of points can be made to support the notion that the pattern of blood supply changes in the wake of bone loss along the alveolar crest. The main purpose of the extensive intrabony blood supply, which is without parallel in the human skeleton, is to nourish the teeth and to fight any infections associated with their presence. Otherwise, the mandibular artery would have to communicate with the “mandibular vein” after the terminal branches and capillaries contained in the teeth and periodontium have been lost.

Against the background outlined above, one of the essential problems with crestal implants in resorbed ridges appears to be that the interior blood supply needed to offer immune defence and enossal force transmission has been almost or completely drained by the time of implant placement. BOI implants, by contrast, mainly require the periosteal blood supply and drainage to be integrated and for force transmission to be supported. This blood supply will be available equally well at any age, even in situations of advanced ridge resorption. More importantly, it can be regulated much better and faster than the intrabony blood supply of the maxilla and mandible.

Any removable restorations inserted in the posterior segment will influence jaw movements by significantly reducing the vertical range of masticatory movements and reducing the lateral excursions in a matter of only around 2 years (Tallgren et al. 1989). These functional alterations will give rise to the qualitative changes in jaw morphology commonly observed in patients wearing dentures. Similar results are seen when the occlusal table on fixed restorations is small.

Conversely, the same functional alterations can give rise to a gain in bone volume after BOI treatment. The reader is referred to Chapter 9.3 for an exhaustive discussion of this mechanism.

² If bone really were to resorb under pressure, the bones in our feet would have to be shrinking – particularly the heel bone! People would be buying smaller shoes and shorter trousers on a regular basis.

Evidence for the existence of a relationship between drainage conditions and bone volume has been provided by Yaffe et al. (1994), who unilaterally mobilized mucoperiosteal flaps in the mandibles of rats, which were then immediately repositioned without suturing after only 30 s. The jaws were histologically followed up by comparing both sides after 3, 7, 10, 21 and 120 days. Massive resorption of the alveolar and endosteal bone was present after only 10 days. The impressive pictures in that report clearly show how much internal damage can be caused by external flap formation if no draining osteotomy is left after closing the flap. Bilateral (i.e. lingual and vestibular) flaps resulted in a greater degree of resorption than unilateral flaps, as the bloodstream is cut off altogether. After 120 days, the alveolar ridges were largely restored. It follows that this atrophy of internal bone structures is due to insufficient drainage, which in turn will cause the incoming blood supply to be reduced as well, thereby causing undernutrition. The open slots following the insertion of BOI implants are presumably capable of preventing this stasis.

9.1.6

Aspects of Periodontal Disease

During the development of periodontitis, the overpressure generated by the external periodontal tissue appears to obstruct drainage from the interior of the bone, which eventually leads to a deleterious state of stasis. Wang et al. (2003) showed that the average interstitial pressure will be elevated in situations of venous stasis and thus may influence at least the formation of periosteal bone.

In addition to directly influencing bacterial cultures, dental ultrasonic therapy apparently has a mechanical effect on this stasis and helps to restore regular flow conditions particularly in those regions that are not subject to the rhythmical bloodstream – i.e. in the osteonal structures where the internal flow of nutrients and waste products are conveyed by capillary action and mechanical deformation of the bone. The reason why peri-implantitis therapy often fails may be that the rough surfaces are re-populated by microorganisms already during the healing phase that will immediately enhance the blood supply and cellular granulation, thereby impeding drainage. Compression screws featuring wide windings might therefore be less susceptible to peri-implantitis than solid screw implants, as the flanks of the windings will direct the intrabony bloodstream away from the implant. Moreover, osseointegration is synonymous with vertical corticalization in crestal implant designs. However, since cortical bone structures decelerate the flow of blood and nutrients, periosteal nourishment and periosteal drainage are important,

but they are automatically disrupted after surgical treatment of periodontitis with flaps. Around implants, the transport of nutrients is greatly impeded by the implant itself, the blockage depending on their diameter and length. Short implants featuring surfaces that allow internal perfusion (e.g. Osseopore implants) have been successfully employed both in dental implantology and in orthopaedic surgery. These designs overcome the problem of nutrient conveyance by having a permeable surface. The longer these implants, the less likely they will survive, since the perfusion effect is reduced with increasing length, and mineralization in the interface area is reduced as well as bone areas of different macrotrajectorial orientation are crossed by the implant.

As soon as plaque-induced gingivitis results in a swelling of the gums, there is a risk that the flow of blood from the periodontal perfusion space is halted or at least impeded. If this happens, and if the perfusion of the bone is compromised as a result, gingivitis will turn periodontitis, accompanied by a bone reaction (atrophy) caused by reduced perfusion. At the same time, the local pH changes, and immunological competence is decreased.

For the reasons stated above, we regard it as an open question whether bacteria are really causally involved in the progression of periodontitis in the way we are taught to think. Ximenez et al. (2000) showed that the bacterial composition observed in periodontal pockets is also present in the supragingival plaque of patients with healthy periodontium. After all, it would be conceivable that those opportunistic microorganisms may be attracted by the degradation products of the increasingly undernourished periodontal pocket and may advance deeper for different reasons at a later time. In other words, the stasis that will eventually give rise to bone resorption may be caused by a gingivitis-related pressure reversal in the peripheral periodontal vessels. By way of analogy, no observer would assume that the vultures sitting on a dead gnu in the African savannah have actually killed the gnu. Current periodontological thinking does, however, assume that the bone is actually attacked or by the bacteria. Now, while there is no doubt that bacteria will facilitate the progression of periodontal disease, there are numerous indications arguing against their causal role in bone resorption.

It is well known that the anchorage of functional teeth in their bony bed is increasingly lost as periodontal disease progresses. As a consequence, microcirculation is reduced. Loginova and Krechina (1998) showed that microcirculation following the onset of masticatory function (as assessed with chewing gum) increased by 70% in the absence of periodontal disease. In moderate disease, the increase

was 19–31%. In cases of severe deep periodontitis, however, the situation was reversed, i.e. circulation would even decrease by 6% (Loginova and Krechina 1998). The authors attributed this finding to changes in vascular micro-architecture involving, among other things, a reversed pressure relationship in the periodontal vessels. In this situation, the crestal segments of the periodontium are supplied from the periosteum and mucosa, while the basal segments continue to be supplied from the enossal space. Under normal pressure conditions, the enossal blood supply would drain to the periosteum and mucosa, but in the specific situation of acute infection, drainage is obstructed by the internal pressure increase in the crestal periodontium. Therefore, periodontitis is essentially a disease in which the bone is depleted of nutrients as the blood flow is undermined by blocking the drainage. The volume of the undernourished bone structures is reduced and it will be replaced by soft-tissue structures. These tissues are susceptible to inflammation caused by the numerous degradation products of the bone in general (enzymes, etc.) and the osteolysis-related high ion levels in particular. The newly formed periodontal tissue structures at the depleted alveolar crest are, in their turn, not particularly well suited to resorb these massive ion concentrations and bone degradation products. In order to ensure drainage of these products, the blood circulation through the crestal periodontium needs to be increased, which becomes clinically manifest as a heightened bleeding tendency.

Some indications to this effect are known to all dentists. Whenever teeth surrounded by large granulomatous regions are extracted, the granulomatous tissue will bleed heavily. The bleeding will stop quickly once the granuloma tissue has been removed. Thus the bleeding originates not in the bone but in the soft tissue. The bone frequently shows large cribriform openings in the contact area with the granuloma without bleeding from these openings when this tissue is removed. The same effect can be observed at childbirth where uterine haemorrhage is stopped quickly after the placenta has been dislodged; if the separation, however, fails or is incomplete, the haemorrhage may persist to the point of becoming life-threatening. Bleeding from the placenta itself is negligible because the lumen of the bloodstream from the newborn organism is too small, which is similar to the blood supply situation in the jawbone; the pressure is thus too low and, more importantly, cannot be regulated upward. In placenta, separate bloodstreams are exchanged at the interface. Jaw granulomas, by comparison, basically stem from one single bloodstream, but the pressure relationships in the area of the terminal branches are such that the pressure coming from the soft tissue prevails. This is

the cause of the progressive development unfolding towards the bone, but originating at the soft tissues. The ancient wisdom of bone surgeons, «God protect us from the soft tissues», expresses the recognition that the bone itself is a reliable partner of our implantological work, but that the development and the healing process of the soft tissues are often cause for concern. This is equally true in periodontology, where the displacement of the hard tissues by the proliferating soft tissues is the very essence of the disease. Bone, as a rule, tolerates less nutrition and a lack of oxygen better than too much of both.

The bone is normally unable, for anatomical reasons, to change its internal blood supply. We doubt that bone that is as well-perfused as soft tissue could remain highly mineralized and that it would remain a substance which would be recognized as «bone» at all. It seems likely that overload osteolysis at disk plates occurs due to high perfusion initiated by the healing process after numerous cracks have occurred in the same region of the cortical bone. An accumulation of porosities due to pronounced remodelling may also contribute to the development of cortical defects of this type.

Quite a few questions remain open about the nature of bone at the nano scale. It is clear that the molecular structure of bone is responsible for the strength of the final product (Landis 1995; Huajian et al. 2003). This may imply, however, that the widely used engineering concept of stress concentration at flaw locations may not be applicable at the level of those nanoparticles of which bone consists. The results of the investigations and ideas of Frost presently form a sufficient basis for the implantologist's work within the jawbones.

9.1.7 Role of Direct Bone Stimulation in Crestal Implants

From today's vantage point, it is doubtful that vertically osseointegrated implant surfaces can stimulate the bone sufficiently to ensure that the bone volume is maintained. At least in the collar area, the forces that would cause the bone to remineralize will often be weaker than the forces promoting demineralization as a consequence of bacterial attack. This process gives rise to the crater-style collapses seen with crestal implants. In order to prevent bacterial retention, some crestal implant types come with a hybrid design in which the crestal segments do not feature surface enlargement. These designs have mainly been used for implants with very small threads and without horizontal load-transmitting surfaces. From the fact that these smooth surfaces are not capable of transmitting loads, it follows that even implants featuring vertical load-transmitting

surfaces need to undergo basal osseointegration if they are to survive in an environment like the jaw characterized by high bacterial loads.

Although electric potentials are known to be capable of influencing the mechanism and direction of bone healing, it has not been demonstrated that electromagnetic fields applied directly on titanium implants can promote «healing» of the peri-implant bone structures (Buzza et al. 2003).

9.1.8

Force, Deformation, Pressure and Flow

As BMUs are formed, the bone becomes more porous and thus less resistant. The degree of mineralization in remodelled bone is 20–35% lower than in fully mineralized primary bone structures. The loss in tensile strength is greater than the loss in shear strength. When the elastic range is exceeded, plastic deformation will occur even in osteonal bone, and it will occur earlier in remodelled areas. The attainable level of plastic deformation is highest if the direction of the incoming load is parallel to the osteons. If an equivalent load meets the osteons axially, the attainable level of plastic deformation is smaller.

Osteonal perfusion is caused by the pressure and frequency of blood circulation (10 mm Hg at 2 Hz) and muscle contraction (30 mmHg at 1 Hz); the most important aspect, however, is mechanical loading (100 microstrain at 1 Hz). Capillary forces play a role as well (Wang et al. 1999). Permeability across cement lines is, however, irrelevant. An increase of stress cycles per time unit will, however, result in a more pronounced fluid pressure gradient near the osteonal canals.

9.1.9

The 0–1 Property and the Self-Trabeculation Model – Micromodelling

Bone is a material that is capable of developing a trabecular structure by itself. Bone is also capable of changing the distribution of the load transmission task between different areas inside the bone or within the cortical bone (Mullender et al. 1994). A hypothetical perfectly homogeneous isotropic bone block would become increasingly anisotropic on being subjected to functional loading. In this process, it would develop both areas of heightened and areas of reduced mineralization. This behaviour is known as the «0–1 property». This behaviour is actually quite amazing, as the contact areas of the trabeculae, if for purely mathematical considerations, are always likely to be associated with peak stresses and hence with osteolytic tendencies. This effect, which is known as «checkerboarding», clearly indicates that we are unable to capture the true crux of the matter

with our mechanistic thinking and mathematical systems such as FEM models, since all these approaches fail to account for the fuzzy behaviour of live bone. Mechanical testing of bone properties will per se induce bone remodelling, thereby causing the mechanical properties to change.

9.1.9.1

Clinical Application

The high clinical relevance of the 0–1 property becomes clear if we consider the following points:

- When the implant is inserted into the bone, the macrotrajectories in the slot area are interrupted. In the healing phase, the situation may arise that the bone areas near the disk are mineralized better than the immediate area of insertion due to self-trabeculation of the cortical bone. In other words, the immediate area of insertion becomes the o-area, while areas in the extended vicinity become 1-areas. The risk that this situation may arise is smaller in the mandible than in the maxilla. The stress-related mineralization pressure in the mandible is higher at strategic implant positions.
- Whenever a large number of implants are inserted in the maxilla (particularly triple-disk or double-disk BOI implants in conjunction with long screws), the vestibular macrotrajectories are largely destroyed, and a healing process ensues that is undefined in terms of trajectory orientation and in which the effects of the implant surface prevail. Biomechanically, the situation can be compared to the grafting of large bone blocks (e.g. from the skull). Bone grafts of this type are not subject to any defined function during healing either. Therefore, implants to be loaded at a later time can basically be inserted right away in the same session. However, treatment with BOI implants offers greater advantages compared to grafting because these implants are inserted into native vital bone that will recover its macrotrajectorial properties faster.
- The anisotropic properties of bone are massively changed or neutralized by inserting BOI implants in large numbers, so that the bone becomes virtually isotropic. When the anisotropic properties are later recovered, some portions of the BOI disks or even the implants themselves come to be located in 1-areas, while other parts will be located in o-areas. This will, of course, influence the clinical mobility of individual implants. As functional alterations converting 1-areas to o-areas and vice versa are always possible over the years, implant mobility does not change the probability of implant survival in any significant manner. Therefore, it takes a lot of experience to appreciate whether a BOI implant should be removed.

- As additional implants are placed next to slightly mobile (ailing) BOI implants, the newly forming macrotrajectories are destroyed once again, which will normally result in both basal disks being integrated. Any granulation tissue that may have formed naturally has to be removed from the mobile disk. Bone grafting material can also be added, provided that the slot area does not communicate with the oral cavity. The longer remodelling phase of the bone grafting material may, at least in theory, cause the area to be once again trajectoryally demarcated as a o-area.
- The o-1 concept is also reflected in implant designs. Clinical results had shown that double-disk BOI implants with a disk-to-disk distance of 3 mm tended to give rise to bone loss on the crestal plate in 10–25% of all cases. This effect may have been due to the fact that the two plates interfered with bone healing as they defined the direction of the trajectories. For example, both plates may have generated overly adjacent 1-areas. These problems were no longer observed when the disk-to-disk distance was increased from 3 mm to 5 mm or when two disks of different resilience were used (the crestal disk has featured only one web bar ever since).
- If BOI implants are inserted immediately after extraction, chances are that the entire bone area will be remodelled completely according to new macrotrajectorial criteria, so that direct interface contact will prevail in the early postoperative phase. This will promote implant healing. It is important, however, to reduce protruding alveolar walls from vestibular direction since the sockets will not be refilled with bone to the same width than when the tooth was still present. If reduction is not required for aesthetical reasons, membranes may be considered as additional treatment option. Secondary augmentation is also a good treatment alternative. The threaded pins have to be advanced far into the palatal native bone, taking the asymmetrical shape of the alveolar bone into consideration. A negative effect on the preservation of equal mastication can be expected from unilateral extractions, as the masticatory forces and new distribution of o- and 1-areas will sometimes intrude on the implanted side, but staying clear of the level of the contralateral side. Therefore, these cases must be adequately and periodically followed up. Treatment concepts based on multiple implants need to be considered as well.

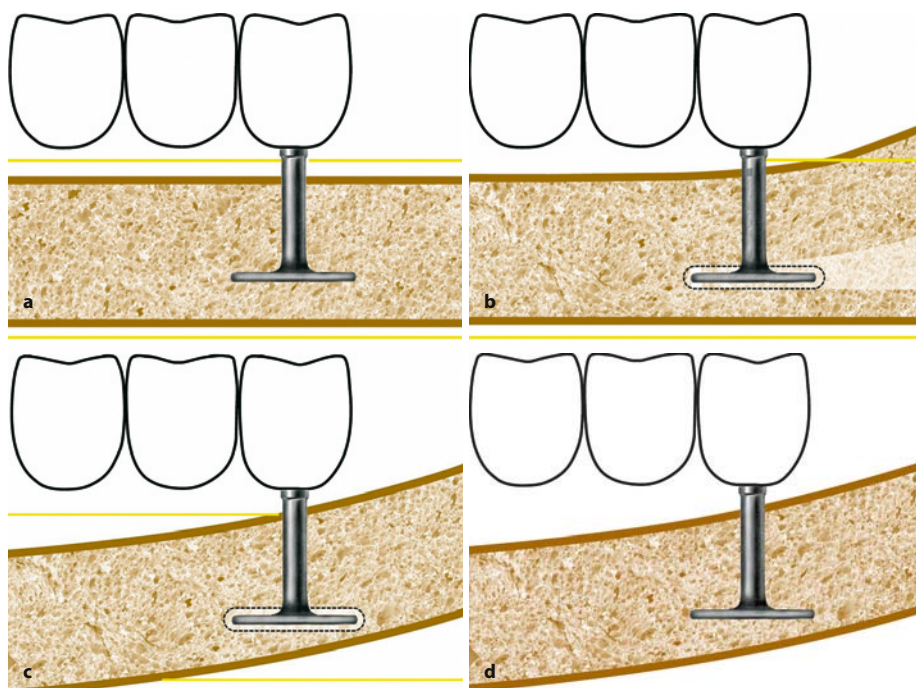


Fig. 9.6a–d. These diagrams show a strictly horizontal trajectoryal bone segment into which a BOI implant is inserted (a). Within the framework of bone defect healing, the orientation of that part of the bone changes (b). This means that the BOI implant may temporarily find itself in a remodelling area (o-area) and become mobile (a–c). However, as long as the BOI implant was inserted into a region of the bone that will remain stable in the long term, the bone areas located around the basal plate will remineralize and unite to form a new macrotrajectory, and the implant will stabilize (d). The bridge must keep all external forces constant and within acceptable dimensions. Internal structural changes in the jawbone will not always result in changes in shape that are easily discernible from outside

- If mobile disk areas are observed primarily in the vestibular aspect of the distal maxilla, additional vestibular load transmission areas can be added with the help of clips (see Fig. 2.34). This approach takes advantage of nearby 1-areas of the bone and enables new bone formation to take place from the site of bleeding:

The following facts should be noted in this context:

Areas characterized by lower mineralization can also have their origin in so-called «acid regions» e.g. in the apical region of endodontically treated teeth. These bone areas are unable to transmit any loads. In their place, other bone areas mature to form 1-areas, while yet others develop into o-areas. From a biomechanical point of view, then, it does not make a difference if a o-zone develops because of excessive flexion (i.e. pronounced remodelling) or because of hyperacidification or changes in vascularization.

The development of o-areas may change the load transmission paths across the entire jaw, even to the point where the survival of implants may be at stake. If implants in 1-areas suddenly end up in o-areas, their stability must suffer. This in turn may have negative consequences for the stability of the entire superstructure and indeed possibly even the opposing jaw. To some extent, the distribution of o-areas and 1-areas can be diagnosed preoperatively by radiographic examination. However, the preoperative distribution of these areas will be changed by the osteotomy of the implantation process, with the metabolic situation of the bone changing as well (suppuration/drainage, see Chapter 8).

If the masticatory function is equilibrated soon after implantation, for example by immediate loading,

the bone healing process and the redistribution of the o-areas and 1-areas can be steered in the direction of a normal distribution. Bilaterally imbalanced mastication, by contrast, will result in an atypical distribution of mineralization zones.

9.2 Form Follows Function

*Will Zurich stop at this train?
(Albert Einstein)*

This chapter will certainly be the most interesting part of the book for the knowledgeable reader, as the dental literature does not contain a great many synoptic discussions of the facts herein described. The conclusions drawn from these observations, if applied in a consistent manner, would impact upon the entire field of dentistry and would call into question many aspects of what we have come to regard as best practice in our everyday clinical work into question. The compilation of individual factors in the middle of the chapter will provide the reader with more food for thought but will take a great amount of clinical perceptiveness and technical dexterity to be implemented. The quotation above characterizes the theory of relativity. With regard to the morphological changes caused by dental implantology and subsequent prosthetics, we might want to use a different wording: Where is the real reference point within the jaw bones?

May the quotation above sharpen the reader's awareness of the consequences of absolute relativity and of the all-embracing interdependence of all

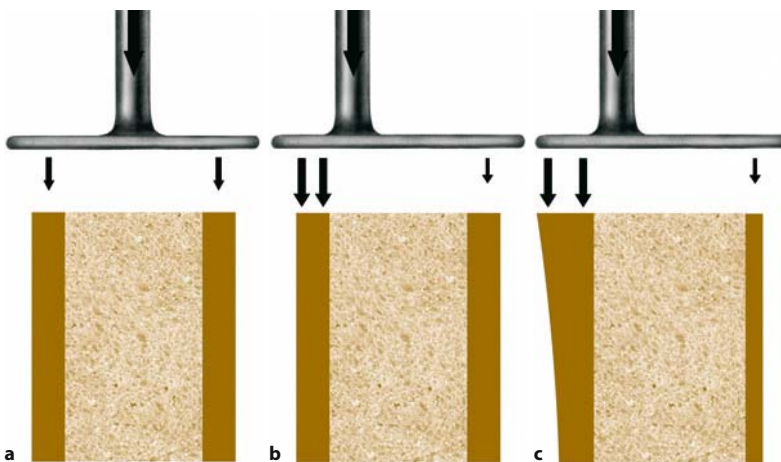


Fig. 9.7a-c. Another aspect of the self-trabeculation model of the bone is observed if masticatory loads are applied via asymmetrical BOI implants; a shows the situation with a balanced load: the thickness of the cortical tissues remains unchanged in the long term both on the left and right sides. Asymmetrical BOI implants increase the load on the side on which the disk is shorter, creating more bone, even allowing the side that is less heavily loaded (here: right side) to develop into an o-area. This situation is often found in the maxilla in the regions of the second premolar or the first molar

changes in jaws with intact dentitions and in jawbones with implant-supported restorations. Due to the gradual development of morphological changes, dentists and patients are often not aware of their extensive implications. As a result, these changes are not followed up properly, and they are utilized much too rarely for therapeutic purposes.

Our daily work with BOI has taught us to focus our attention primarily on masticatory function, since the role of mastication is much more important than the concept of static occlusion. The differences of BOI compared to conventional prosthetic approaches relying on natural teeth and crestal implants are substantial. For example, the usefulness of reducing the width of implant-supported teeth has never been demonstrated, although the demand has frequently been raised (Mericske-Stern 2000).

In situations where well-anchored teeth with long roots or long crestal implants are available in adequate numbers, the points discussed in this chapter might seem not all that important. After all, long-lasting structures (i.e. structures lasting out the warranty period) can be built on foundations like this even when any masticatory considerations are completely ignored. Nevertheless, any screw fractures, porcelain chipping, periodontal tooth mobility and/or implants lost will indicate that forces are present that are not tolerated well or that biomechanical developments do not seem to unfold according to plan.

Anyway, the BOI implantologist rarely gets to work under such favourable conditions but is usually faced by advanced vertical ridge resorption allowing only extremely small force-transmitting areas to be inserted into the bone. Therefore, any excessive prosthetic loading needs to be avoided or eliminated. On the other hand, BOI implants will allow some freedom with regard to the length and nature of the chewing surfaces.

In addition, the effects of the masticatory function on bone morphology need to be considered as well. The following list provides some food for thought:

- Jaw areas that are not per se stimulated by the load-transmitting disks are nevertheless subjected to functional loading. In the presence of equal muscle function on both sides of the jaw, any morphological differences are slowly evened out. As a prerequisite, the prosthetic restoration has to ensure a bilaterally uniform function (chewing function, number of chewing surfaces, length and position of chewing surfaces, muscle function and, by implication, muscle strength). In order to maintain this balanced function, occlusal adjustments have to be performed on a regular basis.
- The rigid bridge will become part of the system itself and actively change its morphological surrounding. If, for example, complete bridges are

inserted into jaws that are very dissimilar in shape, a process of morphological assimilation will take place. During this process, the osseointegrated implants are subjected to considerable stress. Patients themselves might not notice this stress as, e.g. subacute „pain“. Some patients will notice the tension as soon as the bridge is temporarily removed.

- Primary restitution in the healing phase following implant placement, notably in the mandible, is achieved by deposition of periosteal bone on the one hand, and by formation of woven bone in the osteotomy slots on the other. Subsequently, the osteonal belt is rebuilt by BMU tunnelling across the jaw, which now undergoes a process of thorough remodelling. Increasing chewing forces and changing masticatory patterns will also prompt the jaw to change its morphology. The patients report similar stresses as patients wearing freshly readjusted fixed orthodontic appliances.
- Areas that had been reduced in response to the insertion of dentures are able to develop in all directions defined by the modified function. Thus they can also develop towards the occlusal aspect (see Chapter 9.3 for a more detailed discussion), provided that the stimulus is not pre-empted by stronger stimuli coming from the prosthetic superstructure or implants. As a case in point, expansion (apposition/modellation) of the bone in crestal direction, which would be possible from a functional standpoint, is thwarted by chronic peri-implantitis in the presence of large-diameter crestal implants, but also by the overly deep and chronically infected transition zones between the abutments and those implants. This is not the case with BOI implants, as we shall learn in the section on histology.
- Particular attention must therefore be devoted to cases in which the load-transmitting surfaces of BOI implants come to be located in bone



Fig. 9.8. Preoperative clinical situation. The maxillary is restored with a complete denture; a cross-bite has been adjusted on the right. Natural dentition in the right mandible, partial denture in the left mandible (supported by a clasp on the mesial and by periodontium on the distal end)

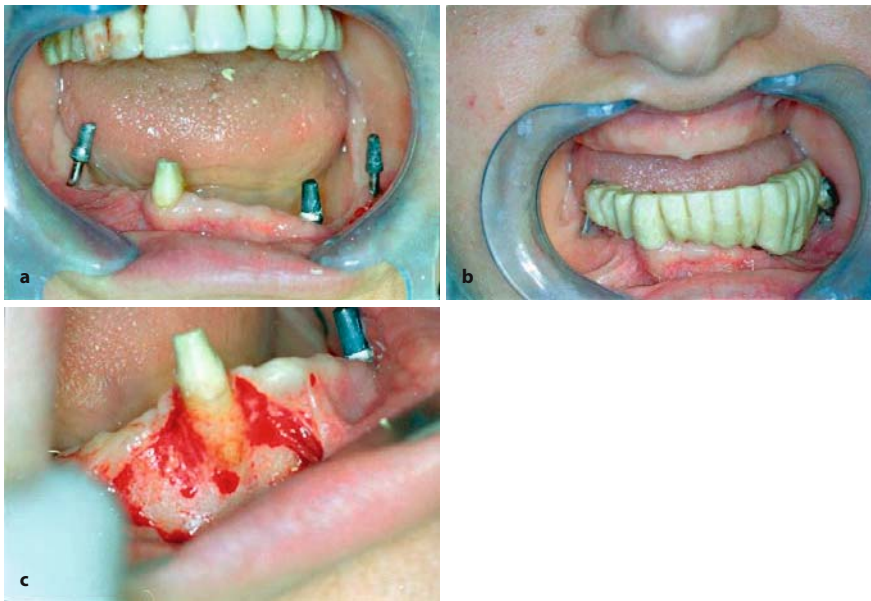


Fig. 9.9. **a** The postoperative situation is characterized by considerable vertical differences within the mandible. If the residual natural tooth is preserved, it will be impossible to balance the volume by reducing the right side, as this would cause the tooth to intrude. Accordingly, the volume of the left ramus has to be increased. **b** At the patient's request, tooth 43 was left in place for the primary fixed restoration. The bridge includes a cast framework and is covered with porcelain. Note the midline shift, which is already reflected in the bone structure. For functional reasons, the area 44–46 had undergone substantial resorption within a short time, giving the bony surroundings of the roots of tooth 43 a prominent appearance. The tooth has a very exposed position. **c** The cortical bone on the vestibular aspect of tooth 43 is extremely thinned out and partially fenestrated. Nevertheless, this tooth was kept until the new equilibrium in the mastication was found



Fig. 9.10. Tooth 43 was eventually replaced with another BOI implant prior to inserting the second bridge because it was likely to succumb to resorption sooner or later despite the considerable stimulus coming from the periodontal ligament. Note that the distal pontics must be located well above the mucosa, since the mandible is going to grow in a crestal direction, which may result in pressure spots or lever forces



Fig. 9.11. Baseline OPG. Extreme resorption on the left; the right ramus is, if anything, hypertrophic

areas that will undergo relative migration in the postoperative course. Due to their osseointegration, the implants themselves will move along with the bone. With regard to the relative vertical increase or migration of the crestal cortical bone in the distal mandible, this means that excessive prosthetic loading may occur in this area. After all, premature contacts are likely to emerge as the implants migrate upwards unless other factors

offering vertical compensation come into play as well, such as elongation of the mandibular ramus or relocation of the associated TMJ.

- Bone morphology changes as masticatory forces are being restored to their full potential. These changes will depend on the patient's age and metabolism. Any changes in bone shape and function, or in bone function alone, is followed by specific defined changes in internal bone

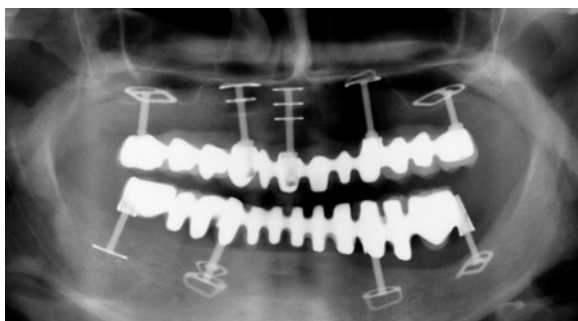


Fig. 9.12. OPG obtained after insertion of the second mandibular bridge and restoration of the maxilla. The process of mutual jaw volume compensation can now be accurately monitored and needs to be facilitated by periodic occlusal adjustments with abrasive instruments (e.g. in the third quadrant). The fixed reference point of these implant-restoration systems is the occlusal plane. Spontaneous reconstruction of the vertical bone volume may take place either above the disks, or the implant has to move upwards together with the surrounding bone, which is only possible if an adequate occlusal clearance is established by abrasive instruments. The implant at 33 cannot osseointegrate in a definitive manner under these conditions. It is continuously under stress, which is noticed by the patient



Fig. 9.13. The pontics need to be periodically reduced from a basal direction

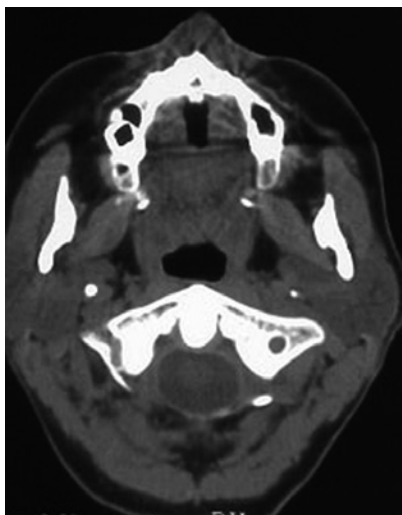


Fig. 9.14. CT overview over the trans-sinus BOI implants in the posterior maxilla



Fig. 9.15. Cranial PA (calculated on the basis of the CT) after treatment. Note that only minimal residual bone is present in the maxilla. Those bone areas are resistant to further resorption because a macro-trajectorial demand for load transmission prevents their resorption



Fig. 9.16. Lateral telerradiograph after treatment. Part of the dentition is not arranged above the osseointegrated support areas, which requires careful balancing

architecture and by equally defined secondary changes in external shape. All of this is governed by mathematical laws (Wolff 1892). While there is no doubt that this statement is true, it remains confined to the changes going on inside the bone. The restorative dentist is faced with a longer chain of consequences. The changed bone shape is likely to be followed by changes in the shape of

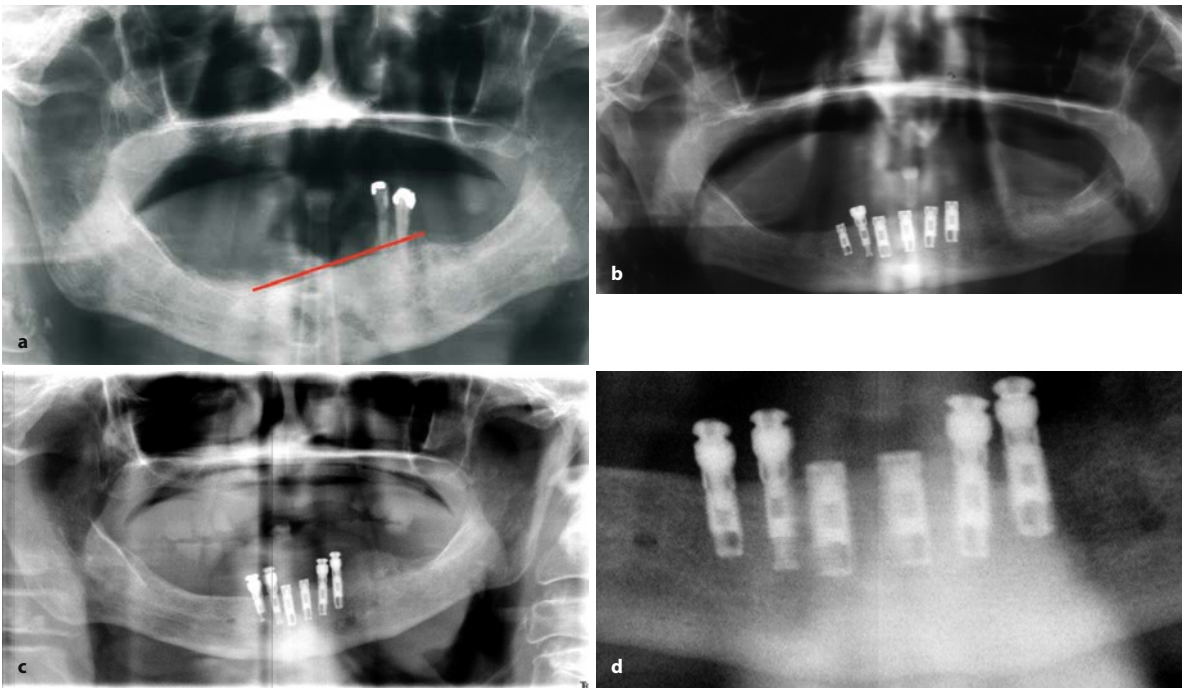


Fig. 9.17a–d. Compared to the baseline picture obtained 6 years previously (Figs. 9.11–9.13), the volume of the mandible appears well balanced, mainly as a result of augmentation of the left ramus. The implants in the left side of the jaw are characterized by crestal bone loss (i.e. collapse) extending to the area that constitutes the absolute horizontal line of this bone. A white crestal line of cortical bone has formed on the right; a mineralization zone excluding the residual ridge can be observed on the left. Despite “correct” isocrestal insertion, bone loss has occurred in those areas where the bone mass and the level of the crest have evened out due to functional influences. Hence the implants on the right are characterized by progressive “bone loss”.³ Due to the relative upward migration of the right ramus under the same prosthetic restoration, the more pliable bone structure in the posterior segment of the maxilla has been forced to regress from caudal direction. “x” indicates the area of localized regression as a denture-mediated answer to bone buildup in the mandible, while the yellow line marks the level and direction of the main load-transmitting line within the tubular bone. **a** Situation after years of wearing a clasp-supported unilateral partial denture. The bone in the area of the premolars has been preserved thanks to load transmission through the teeth. **b** Situation after tooth extraction and insertion of six enossal implants to support a bridge supported by implants only. The second implant from the left is fitted with a healing cap. All implants were inserted at the same “correct” crestal level. **c** At the 5-year follow-up. **d** What resembles a crater-type bone collapse at 34 and 35 is really due to a process of morphological optimization of the entire mandible

TMJ structure and in muscle function (chewing muscles, neck muscles), which will once again influence shape of the bone.

- Reactive migration of the TMJs is frequently observed only several months after BOI-supported complete restorations were installed. Of course, one might contend at this point that the dentist simply may have been unable to properly register the occlusion. Based on our observations, it is

more plausible that the TMJ structures may be decompressed as the jawbone is being remodelled, notably in its vertical dimension. The disk can thus change its position, and the masticatory system with its ever-present tendency of self-healing actually gets a chance to exploit this potential. At any rate, the technique of basal osseointegration offers unprecedented possibilities of functional therapy by allowing load transmission sites to be restored in the distal jaw areas, which are anatomically designed to carry the main burden of mastication. This type of therapy is not confined to influencing muscular structures but specifically offers an opportunity for extensive bone remodelling, for bone volume compensation, and for influencing the biomechanical situation in a physiological manner.

³ Based on the standards used in crestal implantology, this case is characterized by bone loss of more than one-third of the implant length in one-third of all implants 6 years after implantation. Going by these criteria, the implant system would not meet the standards of scientific dentistry. Also see Albrektson et al. (1986).

- As we shall learn in the section on histology, morphology is also influenced by the osteotomy slots. Bone slots inserted into convex bone areas will reinforce the convexity as the bone, which is continuously kept under tension by the chewing muscles, will elastically yield to the slot. Subsequently, the original bone morphology will be restored by way of modelling as the osteotomy slots are being repaired. Since remodelling will also be going on in addition to modelling, mineralization in the affected jaw areas will decrease at large. After all, the tunnel-forming BMU will also extend to well-ossified areas, thereby reducing their osteonal density. If entire jaws are treated with a large number of BOI implants, the overall mineralization can be expected to change dramatically. Presumably, these effects are more pronounced in the mandible than in the maxilla.
- Thus we are faced with a rather complex system of regulatory mechanisms that are governed by the laws of bone formation but also by the neurophysiological regulatory mechanisms of muscle function. Both mechanisms are not per se directed at accomplishing the clinically desirable healing process, but they sometimes require heavy dental adjustments to be made.
- In terms of its bony architecture, the mandible can be compared to a rachitic long tubular bone.
- The mechanical properties of bone are mainly a function of porosity, degree of mineralization, and orientation of collagenous fibres. Morphological changes result from muscle forces and their effect on individual areas.
- From today's standpoint, the concept of bone transformation as originally defined by Wolff includes the following elements:
 - Optimizing strength for weight
 - Arranging trabeculae in accordance with the main thrust of forces
 - Autoregulation of bone structures by cells reacting to mechanical stress
- The bone initially rebuilt in vertical direction is characterized by porosities that are visible to the naked eye, at least in the superficial area, indicating that different levels of stimulation have taken place at different sites. Bone formation is locally excessive. Principal force directions are formed by remodelling only later. This remodelling can only come to pass if the newly formed areas are mechanically challenged, i.e. if they are put into "clinical service".
- By observing the strengthening effect of including or excluding specific enossal BOI implants, it becomes clear that "osseointegration" really means "osseoadaptation". The bone has different mechanisms of adaptation at its disposal. For one thing, the distance between the mineralized

matrix and the titanium surface can change. The mineralized matrix can act like a "smear layer" to overcome excessive differences in elasticity. On the other hand, it is conceivable that the degree of bone mineralization in the immediate or extended vicinity of the implant may be kept low as well (e.g. by strong continuous remodelling). At any rate, considerable differences in elasticity are possible, and the degree of bone mineralization can vary considerably depending on the requirements present.

- It is reasonable to assume that the degree of mineralization in bone structures undergoing several surgical procedures will change at large. This change in local mineralization will, in its turn, change the overall elasticity of the jaw.
- It is also reasonable to assume that each jaw segment has its own preoperative baseline elasticity as a consequence of cumulative mechanical, inflammatory, hormonal and genetic influences. This baseline elasticity may show considerable intraindividual differences.

Remarkably, the fracture resistance of cortical bone is reduced by 80% and its elasticity module increased by 300% if the mineralization content rises from 59 to 86% w/w (i.e. by 50%). These changes are caused purely by function, and they are also likely to occur in the vicinity of enossal implants, depending on the prosthetic load. In the absence of any other factors, such as inflammations, they are always reversible.

The molecular structure and organization of crystals inside the matrix are crucial determinants of bone strength regardless of the functional tasks to be fulfilled (Landis 1995). The deposition of a well-structured matrix prepares the ground for a

Table 9.1. Mechanical properties of bone (Currey 1981)

Variable	Elk antlers	Cow femur	Whale bulla
Fracture resistance (J/m^2)	6,190	1,710	200
Flexural strength (MPa)	247	179	33
Elasticity module (GPa)	7.4	13.5	31.3
Density (g/ml)	1.86	2.06	2.47
Acoustic impedance ($10^2 \text{ kg m}^{-2} \text{ s}^{-1}$)	3.71	5.27	8.79
Mineral content (wt %)	59.3	66.7	86.4

well-structured mineralization process. With regard to BOI systems, this means that any implant mobility that interferes with matrix formation in this phase may result in abnormal matrix conditions, thus leading to the formation of mechanically inferior bone structures. Hence loading in weak bones (with little primary fixation and little bone flow) should not take place between day 12 and day 40 postoperatively.

An optimized process matrix formation has an important influence on the probability of survival of the implant also in the long term. Clinically, even unfavourable baseline conditions, resulting in inferior matrix formation, will still be able to allow regular initial loading of the implant. Inferior matrix formation may also be corrected, within certain limits, by osseoadaptation and gap jumping. It is also possible that an implant that was “disadvantaged” from the start can function well in the first superstructure inserted, for many years. However, it may very well not survive a change of load resulting from a new, second superstructure. The superstructure used may remain stable after traumatization (accidents, physical fights) during the early mineralization phase. If the bridge is changed at a later point, though, the “corridor” for compensation that the bone can offer will often be left, and the peri-implant bone substance will rapidly exhibit violent osteolysis. This is one of the reasons why the initial service provider should be the one to decide on the future treatment course in problem cases. Any subsequent treatment provider may not know the circumstances prevailing in the first treatment case and may not have the best grip on possible further routes of treatment. If implants whose matrix formation was previously compromised are included in subsequent superstructures, the ensuing loss of their load-transmitting function may well render the entire new restoration unusable. Only he/she knows the full history of the implant and the site. See Chapter 27 for more comments.

In the dental literature, it has been postulated that the anterior segment of the mandible is so resistant because it contains so many muscle attachments. On closer inspection, the number of muscles attachments is not so great after all. Therefore, there must be other reasons for this stability.

In his early study of bone transformation, Wolff already provided impressive illustrations of rachitic long tubular bones, which describes the essential nature of the mandible. The curvature of the mandible is a functional characteristic. The differences to “traditional” rickets are due to the fact that the mandible is deformed by the growth and protruding force of the tongue on the one hand, and by tooth growth on the other. Once the other muscle-related forces in the oral cavity are factored in as well,

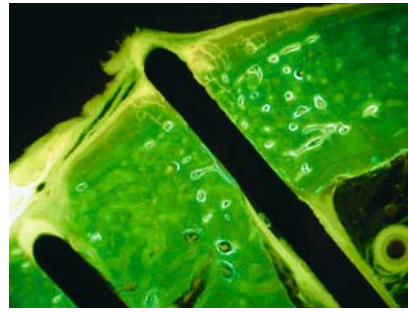


Fig. 9.18. Double BOI implant in a dog's mandible, 4 months after implant placement. Tetracycline labelling reveals that the formation of BMUs at the basal plate is stronger than around the crestal basal plate. Overload in load-transmitting areas of the disk will invert the flow because the demand for nutrients is greater than what the bone itself can offer. In the event that the overload is not addressed prosthodontically, the excess blood supply (relative to what is needed for bone volume preservation) will persist, and the high degree of bone mineralization is reduced because it cannot be kept up under high-flow conditions. This will subsequently destabilize the implant

these processes are bound to result in anterior bone amassment. In other words, the bone concentration is not caused by the muscle attachments in that area but by the sheer morphology of the tubular bone, which is exposed to flexural stresses by the lateral pterygoid muscles during mouth opening.

The position (migration) of the exit point of the mental nerve can ultimately also be explained in these terms. In many patients, this point moves away from the anterior cortical bone area towards the distal aspect through the premolars as the vertical dimension increases, eventually resulting in the characteristic “loop” in the radiograph.

Before the switch to the permanent dentition is completed, the mandibular nerve canal is located rather deep at the lower border of the mandible. The loop is not visible in children. Only when the permanent teeth erupt will the canal grow over varying distances in crestal direction. The loop will form if distal migration of anterior teeth and bone volumes takes place due to functional incentives during vertical growth of the mandible. This may happen, for example, in class-II/2 patients with elongated fronts or in patients with compensated class III relationships. The radiographic shape of the mandibular nerve therefore offers information on each individual's development, indicating growth peaks and allowing conclusions to be drawn as to the cause and development of asymmetries.

Even technically “correct” abuses by means of partial dentures can significantly alter the masticatory pattern and morphology of the jaw. Mandibular form and function ultimately have to be in keeping

Jul Wolff, Gesetz der Transformation der Knochen.

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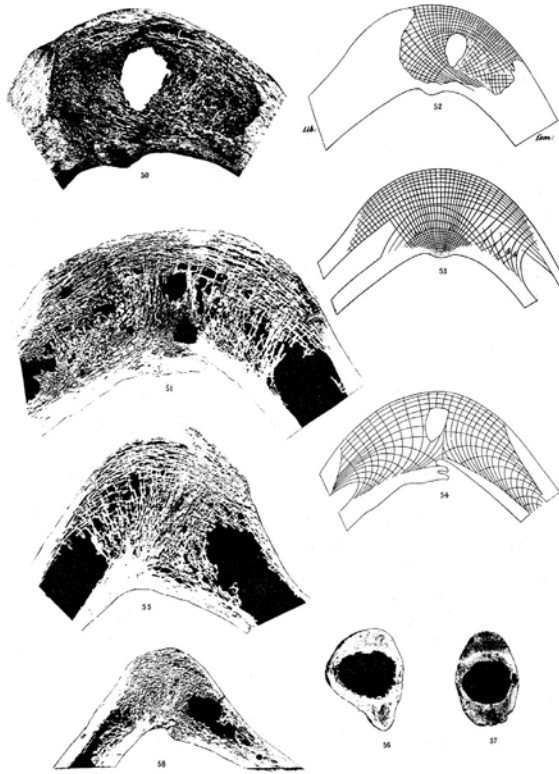


Fig. 9.19. Transformation of rachitic long tubular bones (from Wolff 1892)

Jul Wolff, Gesetz der Transformation der Knochen.

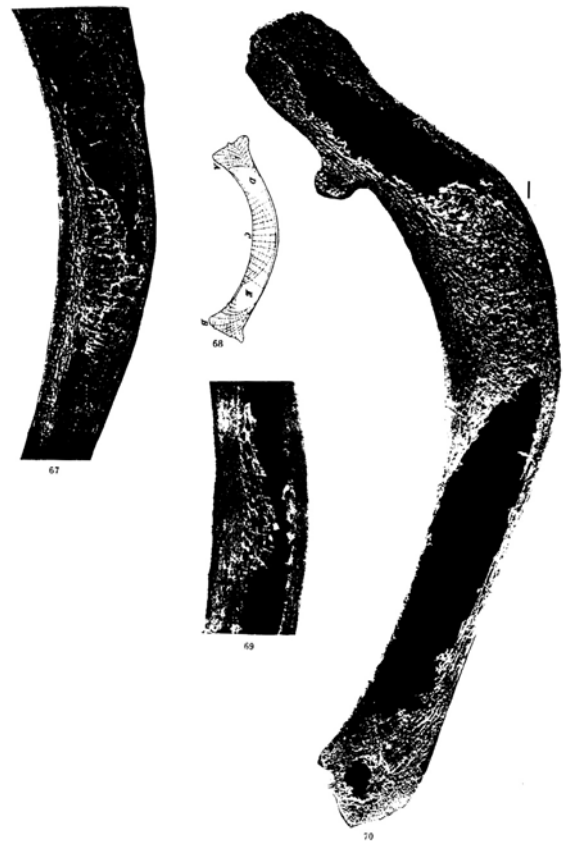


Fig. 9.20. Transformation of rachitic long tubular bones (from Wolff 1892)

with the BOI system. If there are great functional differences between the preoperative situation (with a partial denture) and the planned BOI-supported restoration, the road to success may be encumbered by complications such as implant loss, osteolysis and fracture.

These alterations require complete remodelling of the entire mandible and, in addition, modelling in crestal direction. The load-transmitting trajectories were rebuilt from scratch. It is fair to say that what we see is, biomechanically speaking, a completely “new” or “different” mandible. In retrospect, it is hardly surprising that this outcome should have been preceded by recurrent episodes of overload osteolysis and implant fractures. Including a case like this into the BOI survival statistics uncommented would not do justice to its specific nature. What matters at the end of the day is the clinical outcome, which however would have been unattainable without the patient's exemplary attitude and collaboration.

The structural alterations observed in this patient would be inconceivable in the absence of a changed mastication pattern (Neufeld 1958).

These are the differences in detail:

- In the baseline situation (Fig. 9.22), the partial denture forced the distal part of the mandible in caudal direction, thereby generating undermineralized crestal areas. In order to resist the masticatory forces after all, heavily mineralized areas are formed at the lower mandibular border protecting the mandible against fracture. The anterior restorations in mandible are splinted, kept in place with distal ball retainers, and stabilized by a continuous attachment. The mandible would need to gain crestal volume in this situation but is prevented from doing so by the masticatory pressure. Only the support of the anterior teeth against the vestibular cortical bone of the anterior mandibular segment prevents those teeth from yielding to the distal lever force outright. As a result of tooth mobility, the crestal anterior area of the mandible is rather soft. These desolate baseline conditions were basically iatrogenic in nature. They would have been unattainable without the extremely misguided therapeutic approach of anterior splinting combined with ball retainers and

an attachment. On the downhill scale, this patient ranks very low indeed. Biochemically speaking, this is a very complex case. The radiograph shows a tubular bone structure for both distal regions of the mandible.

- At the end of therapy, the white line on the left is beginning to form. Meanwhile, the pronounced zone of ossification at the lower ramus is significantly reduced. The distal implants on the

left and right are in an infranervial and supranervial location, respectively. The ossification process around the distal implant on the right is not too advanced at this point, indicating that more extensive remodelling is going on. Presumably, it would have been better to reinsert the left distal implant to an infranervial position as well. In both distal regions of the mandible, the radiograph shows almost complete dissolution of the tubular

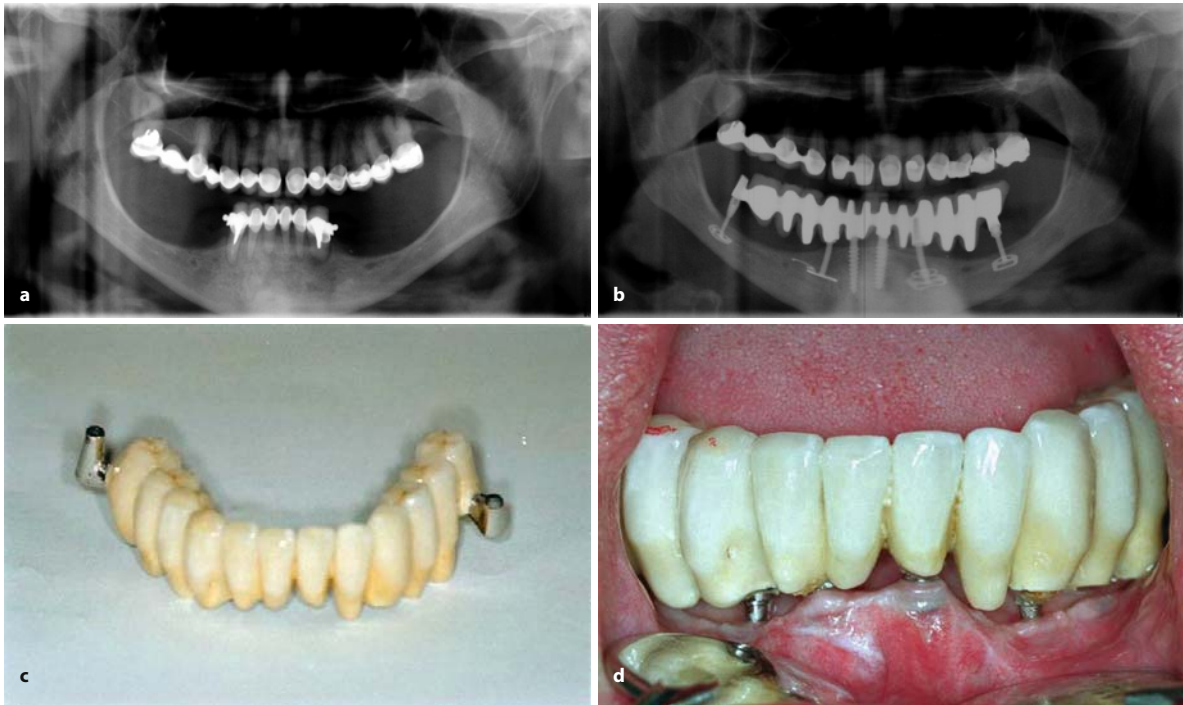


Fig. 9.21a. The preoperative situation is characterized by massive resorption of the distal mandible with a thin cortical bone volume along the distal ridge. The patient wears an anteriorly retained partial denture and shows powerful chewing forces on clinical examination. The basal edge of the mandible is extremely massive and extends seamlessly back to the area of the mandibular angle. The chewing pattern is balanced, as morphological differences between the right and left sides of the jaw are not present. **b** Successful outcome following multiple implantation procedures and some implant fractures. The basal zone of ossification has completely dissolved. On the right side, the white line has emerged. The distal implant on the left is located in a relatively anterior position because the nerve prevented its placement at a more distal location. For the primary restoration, infranervial placement was required. The vertical thickness of the mandible increased. For 6 months, the patient wore an implant-supported bridge retained in the anterior segment with a reduced masticatory table. By the time this picture was obtained, the tubular structure of the distal mandible (still visible in Fig. 9.22) had been partially dissolved by enossal load transmission. As a result, the anisotropic properties and elasticity of the bone had changed as well. **c** Due to the advanced ridge resorption, the transition areas between the restoration and the implants can only take the form of technical abutments. After all, the opposing jaw is completely intact with natural teeth, and the level of the mandibular dental arch should be such that normal function is ensured. **d** This picture demonstrates the different ways in which the implants influence bone morphology. While the BOI implants easily permit functional adaptation of the bone morphology, the two crestal implants force an increased peri-implant bone level that is apparently “wrong” from a biomechanical point of view. This bone level could not persist under prevailing functional conditions. The mandibular atrophy is a result of the deteriorated enossal vascularization following tooth loss. The question of whether the insertion slots for the BOI implant might intercept/drain the flow of nutrients to the anterior segment of the mandible would certainly be an interesting one to follow up on. Nevertheless, the vascularization of – and thus the supply of nutrients to – the residual bone around the screw implants does not appear too bad. The inflow of nutrients into and the outflow of waste materials out of the bone, i.e. through the mucosa or the periosteal tissues, seems to be sufficient to maintain this amount of bone alive. The nutritional situation of the crestal peri-implant bone is similar to the bony sheath of dental roots in the sinus. The screw implants seem to maintain bone in areas where it is from a functional point of view not needed. Sooner or later function will take a rule over osseointegration and this may be one of the reasons why screw designs tend to show a gradual loss of vertical bone

bone structure as a result of the newly created enossal load transmission pattern.

Therefore, the issue of individual implant risk is associated not so much with a poor baseline situation in terms of available bone volume as with the functional modification and the question how extensively the area of the force-transmitting interface is going to be remodelled. While elasticity of the bony structures is per se a physiological property of the jaws, exaggerated or inadequate elasticity are signs of excessive loading or functional inferiority, respectively (Jung 1952).

Situations characterized by multiple agenesis of teeth offer information on the nature of mandibular growth in the absence of any overlapping between teeth and bone structures. Most of the blood supply in the basal jaw segment comes from the periosteum, while the crestal blood supply is determined by the mandibular artery. This stronger blood supply is necessary because of the high metabolic activity that is going to take place as teeth have to be formed and masticatory forces need to be transmitted inside the bone. Due to the poorer metabolic situation, the lower margin of the mandible will always be able to grow less quickly and extensively, which is the main reason, besides functional aspects, for the relocation of alveolar ridge and the jaw base. Root curvature comes to pass as the root tips grow into jaw areas whose growth tendency runs counter to the alveolar ridge or is insufficient at the time of root growth.

Further lessons to be drawn from Case Study #5:

- Teeth are kept in the same place by the periodontal ligament, or they move through the bone by remodelling. These movements are performed in the absence of any additional direct occlusal or masticatory forces. The bone level at the crest tends to join (in a healthy periodontal situation) the PDL area at a right angle (Fig. 9.23d).
- If true alveolar bone is missing and the crest of the jawbone coincides with the crestal macrotrajectories, teeth cannot elongate even if their antagonist is absent. In a stable periodontal situation, it is not possible to reverse the inclusion of the bone areas around the tooth in the macrotrajectories and to let the tooth elongate along with its PDL. But as Case Study #4 shows, this facility appears to be limited with crestal implants; since it is not necessary to maintain the perfusion structures in the bone near the implant, these implants can elongate along with the interfacial bone.
- Teeth are subjected to these forces even when incorporated in implant-restoration systems. Osteotomies for BOI implants may give rise to substantial remodelling processes, as they will often disrupt essential trajectories.
- If such teeth show an excessive tendency to move as trajectorial orientation of the jaw is being established and if these movements take a different direction than the implants involved, then the implants may be subjected to heavy preliminary stresses, thus being at risk of fracturing. In cases such as these, more implants have to be placed.
- In our experience, these tendencies are frequently encountered with maxillary systems involving teeth 3 and 4 (and 5) on one side while the other side includes a single strategic BOI implant in the canine area. In the presence of only one canine (without ipsilateral premolars), the resistance of the canine to maxillary remodelling tendencies seems to be less widely distributed, so that the canine is not subjected to an excessive migration tendency. The same is true if the premolars or any anterior teeth around individual canines are extracted and replaced with implants in a single-step procedure. The bone remodelling will be so extensive in this situation that even a small number of BOI implants will not be subjected to preliminary stresses.
- Likewise, the prognosis of a single strategically placed BOI implant will be improved by stable distal abutments placed diagonally against the residual dentition.

If a treatment procedure fails, this failure will often shed some light on the limits of function and the reasons for function or failure. The following case gives us an idea of the extent and location of mandibular deformities in patients with unilateral chewing patterns.

Looking at these two cases in context, we can draw the following conclusions:

- The difference in length between the two horizontal branches of the mandible will be balanced-out once the masticatory function has been equilibrated.
- If, during this phase, fixed restorations supported by natural teeth and/or BOI implants are worn, the bone segment containing the BOI implants may be dislocated. This may create tension that may occasionally become so strong that the implant itself fails. Installing rigid bridges supported by many BOI implants and kept strictly apart from natural teeth appears to be a sensible alternative (construction type 2 h; see Chapter 12). The enossal implant surfaces should be smooth in order not to prevent the bone substance from drifting and to facilitate a constantly renewing form of osseoadaptation with spatial adaptation.
- The changes in length in the horizontal branches of the mandible presumably take place in the area of flexion around the second premolar and first molar and are caused by the bone substance drifting apart in this area. This process probably

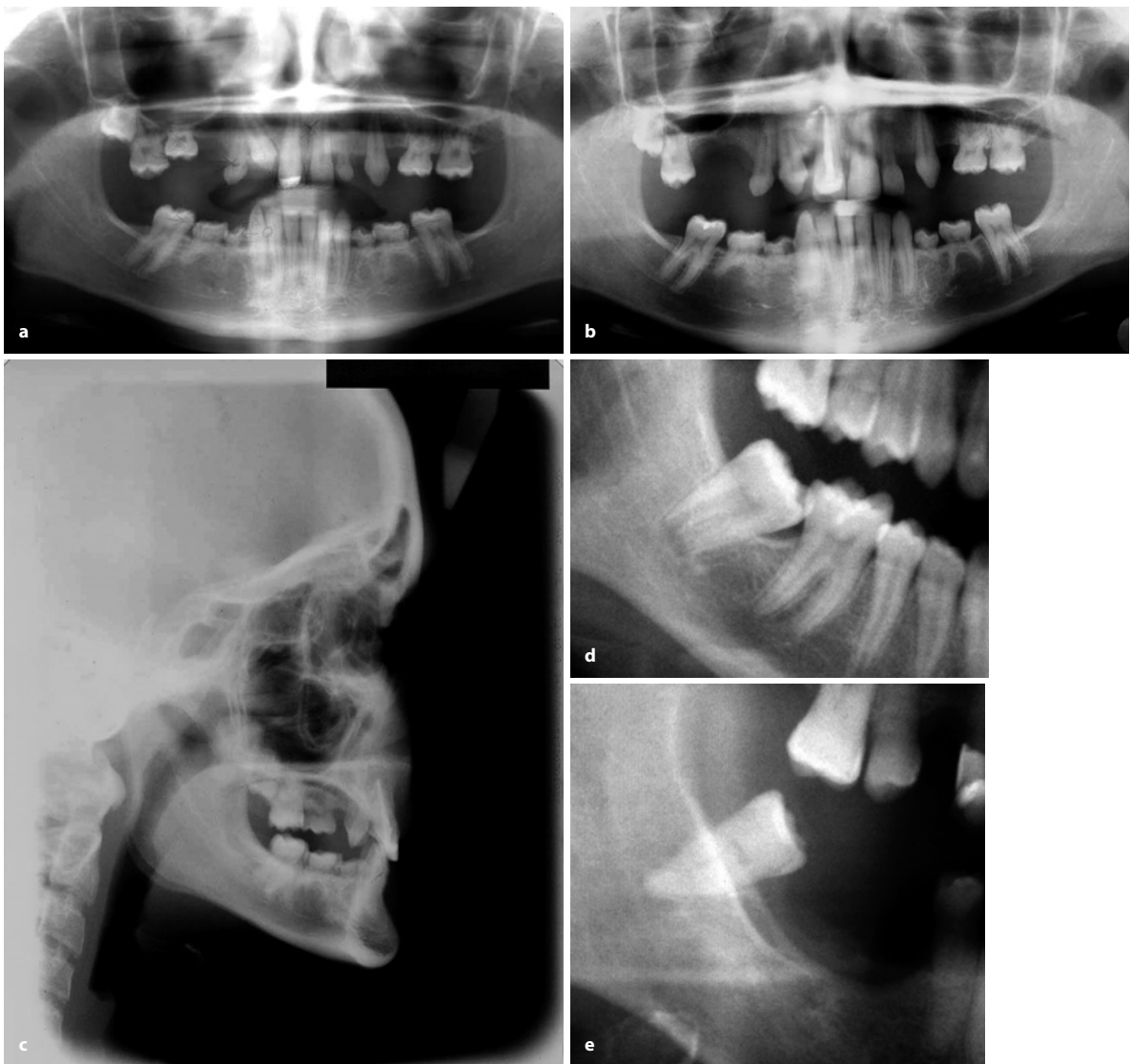


Fig. 9.22. **a** OPG of a female patient at 14 years and 11 months. Note that the dentition in the mandible shows hardly any gaps. Compare this to “Case Study 7” of this chapter and Fig. 23.46. **b** OPG at 15 years and 1 month. Note that gaps are now emerging on the right side. A patient of the same age with intact premolars and second molars would show no more gaps at this point. Anterior growth of the mandible took place through the basal jaw segment; part of the alveolar ridge linked to this structure stays behind towards the distal aspect. The loop is therefore very pronounced. Consequently, the first lower molar and the canine on the right show a reversed curvature characteristic, which is normally only seen with premolars, resulting from the growth-related distal shift of the alveolar bone segment during anterior chin growth. The asymmetric development is caused by chewing pattern, which has moved unilaterally to the left side. The left mandibular border shows more mineralization; the midline has shifted to the left. To summarize, the alveolar ridge and the basal jawbone segment perform mutual shifts. These shifts have a shaping effect on the teeth contained in the jaw and the nerve canal. Basal jaw growth is more pronounced than alveolar growth. In this way, the prominence of the chin is generated at a time when the maxillary anterior segment has completed its anterior growth and keeps the mandibular anterior segment back as well. The bilaterally thin distal cortical bone at the lower mandibular border indicates that the pressure, and hence the chewing load, in these areas is small. **c** Lateral telerocephalogram at 12 years and 1 month. The molars are without contact. In this situation, it was attempted to achieve molar occlusion with the help of elastics to move the molars towards each other. This attempt was successful at first. The patient subsequently reported that she had started to develop posterior chewing. After a short while, she had experienced pain and mobility in the anterior segment and then reverted to her previous anterior chewing pattern (as in class II relations). The molars then almost instantly started to move away from each other, back into infraocclusal position. This behaviour by the molars is unexpected considering the precept of scientific dentistry that all teeth have a tendency to erupt on a lifelong basis. This patient's teeth, being embedded in favourable conditions of intact periodontal structures and osteonal force transmission, showed no inclination whatsoever to erupt further towards the occlusal plane. The distal bone volumes are insufficient to allow the molars to establish contact. In areas with a single tooth only, no alveolar bone develops. **d, e** If the periodontal tissues are healthy, teeth will tend to position themselves at right angles of the surrounding bone (**d**). If the crestal bone level and the macrotrajectories coincide, eruption requires the formation of new macrotrajectories (**e**)

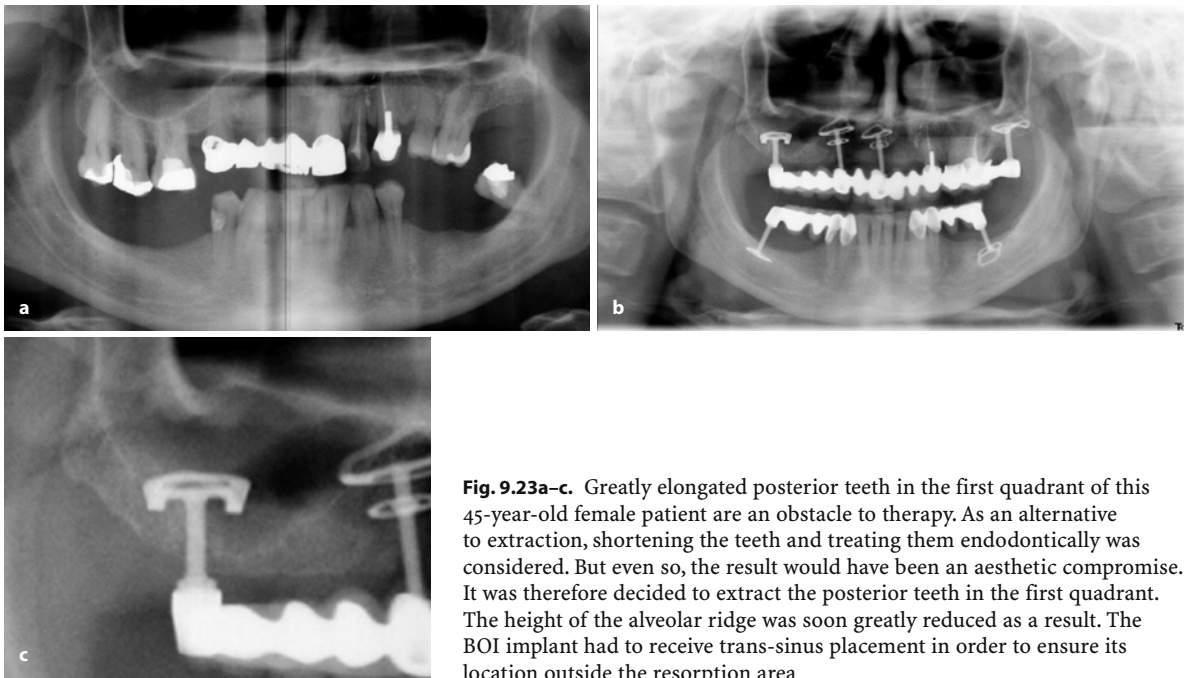


Fig. 9.23a–c. Greatly elongated posterior teeth in the first quadrant of this 45-year-old female patient are an obstacle to therapy. As an alternative to extraction, shortening the teeth and treating them endodontically was considered. But even so, the result would have been an aesthetic compromise. It was therefore decided to extract the posterior teeth in the first quadrant. The height of the alveolar ridge was soon greatly reduced as a result. The BOI implant had to receive trans-sinus placement in order to ensure its location outside the resorption area

takes place throughout life, more or less without being noticed; it can also be visualized by looking at the curving characteristics of the mandibular premolars compared to the mandibular molars. Both groups of teeth thus constantly grow towards each other in order to offset the permanent bone drift they are subjected to. The occlusal relief is of great importance for the definitive positions and orientations of these teeth. Our findings are not consistent with the explanations of Atkinson et al. (1977).

- If the mandibular anterior teeth follow the premolars on their distal path (as a result of soft-tissue areas under tension and a hyperactive orbicularis oris muscle) and the space that becomes available is filled from anteriorly, this will result in a strong, pronounced chin.

9.2.1

Conclusions

In the case studies presented above, some aspects of bone reaction were discussed that are important for BOI treatment and can be summarized as follows:

- Changes in vertical dimension will alter not only the force relations between the jaws, but in the long term they will also alter the architectural structure of the facial skull. The probability of implant survival can be improved solely by

placing the implants in zones which we expect to be present regardless of any other influence.

- On the other hand, it appears that implants may fail even in “safe” positions if an inappropriate vertical dimension was selected, since the newly established mastication pattern may involve a changed, sometimes undesirable distribution of tension and pressure areas.
- The basal part of the jaws will mineralize sooner than the alveolar side, as bone growth and tooth eruption will continuously initiate new BMUs inside the alveolar ridge. These BMUs will prevent ossification until a balanced tooth position and jaw function has been attained.
- Remodelling is triggered once again by tooth loss and implantation procedures.
- Blood supply to the alveolar bone deteriorates increasingly as ossification processes take place after growth has been completed.
- While teeth are present, optimal trajectorial orientation of the bone cannot be established. Following tooth loss, the vestibular trajectories in both jaws move towards the medial aspect. Bone resorption will follow a centrifugal pattern in the mandible, although the macrotrajectories move medially. The maxilla undergoes a centripetal resorption only.

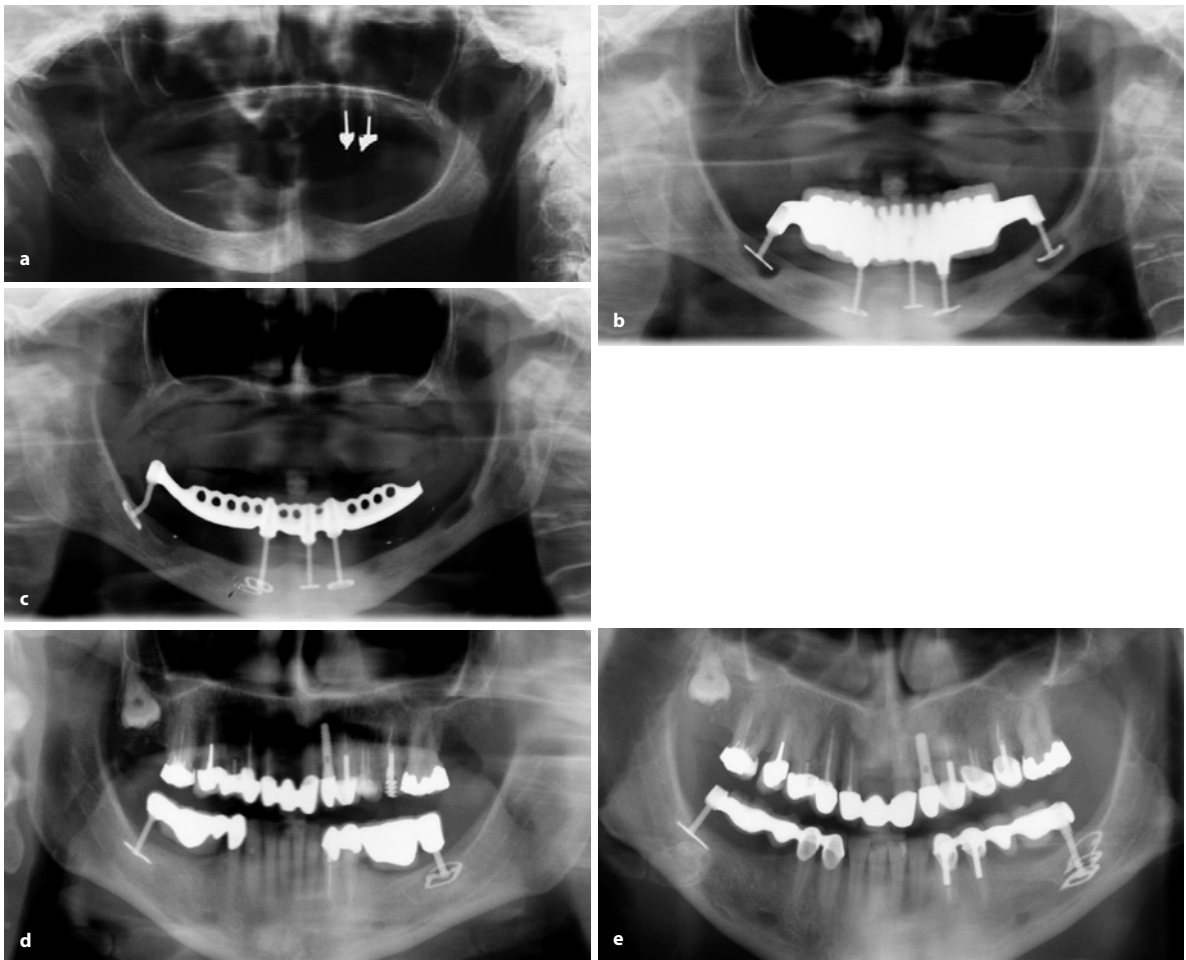


Fig. 9.24. **a** Preoperatively, the patient presented with pronounced mandibular atrophy. The two maxillary teeth had still permitted chewing for many years, but only on the left side. As a result, the mandibular midline had drifted massively to the left. The right horizontal branch of the mandible was stretched in this process. **b** Discrepancies of this magnitude obviously require so much remodelling in both jaws that the two distal BOI implants could not preserve their osseointegrated state. Nevertheless, this first restoration had remained in function for 5 years. By contrast with the situation in Fig. 9.24d,e, osseointegration of the distal BOI implants was certainly not the optimum (although not absent completely), and the patient's oral hygiene habits were extremely unsatisfactory. For these reasons, larger areas of mineralization deficiencies could become established, with the bridge ultimately being supported mostly by the anterior implants. **c** BOI therapy and concurrent equilibration of the masticatory function had the result that the midline could now be repositioned such that the left horizontal branch of the mandible could increase substantially in length and the difference in height between the two branches levelled. The tensions this created were again incompatible with osseointegration of the BOI implant in the region of tooth 37. The implant was removed, and the bridge was left supported by four BOI implants. We assume that after 1 or 2 years, a new implant could be safely integrated in the same region and connected to the bridge. Note the massive morphological changes between the baseline situation and the radiograph taken after 7 years of wearing fixed restorations, with increasingly equilibrated masticatory function. It was not until many years had passed and the two maxillary premolars had been extracted that this masticatory function could be adjusted properly. Completely edentulous jaw quadrants with a few contralateral teeth can be the reason for unilateral mastication patterns. **d** Two posterior segments were inserted first in this patient. Because the pontics had not been reduced on the basal side of the bridge, the implant bars fractured. Contrary to our normal usage, the load-transmitting disk of the left BOI implant was not removed; instead, a new disk was inserted directly below the old disk. (It was possible to re-use the first bridge as a temporary restoration. This resulted in a random relative positional reorientation inside the bone. A few months later, the left implant fractured again. The third disk was again inserted below the second one). **e** The panoramic overview radiograph taken at a later occasion clearly shows an increasing distalization of the disks left in place in the third quadrant as the disks were drifting and changing location along with the bone substance

- In the presence of a unilateral chewing pattern, tensile forces will be acting on the crestal jaw segment of the non-working side. Relative lack of vertical occlusal stimulation will cause horizontal trajectories of the trabecular type to form within the body of the jaw.
- The extent of the extrusion of maxillary posterior teeth can be considerable. Unless accompanied by periodontal destruction, the teeth will “take the bone along”. If such elongated teeth are removed, this will result in a very fast involution of the alveolar bone, which will be reduced to the size it would have had had the tooth not been extruded. The caudal cortical bone of the maxillary sinus limits the involutionary tendency.

In addition to mechanical factors, hormones play a vital role in bone generation and growth-related bone remodelling as well. Implant patients do not belong to an age group where growth effects play a role, but they tend to be afflicted, to some degree, by generalized age involution and disuse atrophy affecting the entire body. Following tooth loss, the bone that the teeth have “brought along” in the growth phase will undergo involution. Temporary growth peaks may even occur in old age following trauma to the bone as mediators are released in large amounts that are capable of inducing new bone growth not only at the immediate site of the trauma but in more remote areas as well (Bab et al. 1985; Baker 1922).

9.3 Impact of Compression and Tension on the Vertical Bone Level

9.3.1 Introduction

Judging from its architecture, the mandible is essentially a long tubular bone (Ashman and van Bushkirk 1987). The chin is an area of maximum flexion in which trajectories from both sides overlap to form a structure of high density. Being a “safe haven” for anchorage, the chin is a preferred site for implant placement. The shape of the mandible is derived from a number of factors. Crucial determinants include muscle function (i.e. chewing and mimic muscles) as well as the number, size and position of teeth. After teeth have been extracted, the related bone structure of the alveolar ridge will undergo disuse atrophy, i.e. the vertical bone volume will be reduced in a clinically manifest manner. The presence of any restorations that are insufficiently supported by residual teeth or enossal anchorage may accelerate this process of bone resorption

(Nähri et al. 1987; Jung 1959), thereby influencing the vertical dimension of occlusion and hence the vertical dimension of the face at large (Smith 1975). Very much like the way we differentiate between load-bearing and non-load-bearing structures in buildings, we can make the same distinction in the jaws. The “load-bearing” structures of the jaws are those areas that possess a trajectorial orientation as a result of masticatory function and are designed to prevent mechanical failure of the jaw at large. These structures are stable to resorption. Bone areas whose principal task is to accommodate the dental roots have no load-bearing function. The distinction is not always clear, however. For example, the basal root segments of lower second molars are frequently located in load-bearing jaw segments, which is good for bone preservation (and thus for the preservation of teeth), provided that appropriate functional patterns are present.

There have been very sporadic indications in the literature that BOI-based restorations are not only able to arrest the bone loss brought about by periodontal disease but also to generate new bone tissue (Scortecchi et al. 2001). Follow-up examinations of implant-restoration systems in heavily resorbed areas of the distal mandible have sometimes revealed considerable new bone formation below and above the load-transmitting disks of BOI implants. Long-term success can only be achieved if the treatment concept duly considers the functional requirements.

We have previously demonstrated that the bone volume in resorbed distal mandibles will routinely increase after local installation and loading of implants (Ihde 2003). In follow-up examinations of 120 patients, we observed bone gains in the range of 0.1–5.4 mm above and of up to 4.3 mm below the basal disk. The distance of BOI implants from the surface of the alveolar crest and the lower border of the mandible tends to increase. In one extreme case, an increase in vertical bone dimension of 6.2 mm was measured.

Increases in bone volume were especially pronounced in those areas where removable integument-supported restorations had been worn. They were greater still in pontic regions where no implants were present.

In unilateral patterns of jaw movement, vertical development of bone is reduced on the working side and enhanced in the area of the 2nd premolar and 1st molar of the non-working side. This will lead to a deformation of the jaw bone and to an alteration of the relationship between the prosthetical workpiece and the crest of the bone. This is due to the fact that the alveolar crest surface of the working side is subjected to compressive forces, whereas the non-working side is dominated by tensile forces.

9.3.2

Background Considerations Regarding Vertical Bone Growth

The vertical component of today's BOI implants (i.e. the threaded pin) is smooth. The surface of the basal plates, however, may be roughened by sandblasting to maximize the available surface (hybrid design). The masticatory load is transmitted exclusively through these basal plates. The use of crestal implants has been described to be associated with continuous vertical bone loss (Schliephake and Neukam 2000). Also, these implants tend to sink into the mandible unless they are supported (e.g. lingually) by cortical bone. This is particularly true of blade implants. No pertinent results have yet been published for BOI implants.

Two patients in whom mandibular implants were placed symmetrically on the left and right sides revealed patterns of bone growth that were essentially unilateral. Surprisingly, the preferred sides coincided with the sides where the vertical dimension had been greater even before implantation. The apposition pattern in these patients was the exact opposite of the pattern seen in all other patients studied.

The results on clinical examination confirmed the finding obtained by interview and observation that those masticatory patterns were purely unilateral in nature, as TMJ function to the contralateral side was almost completely obstructed. Vertical bone gain was observed mainly on the non-working side.

This type of apposition behaviour had been described previously by Hylander (1979). It was attributed to the fact that compressive forces developed on the non-working side of the lower mandibular margin during mastication whereas tensile forces were predominant in the upper portion of the alveolar ridge. The results that Hylander had obtained in monkeys were later confirmed in greater detail in studies on humans performed by Koriath and Hannam (1994) and Dechow and Hylander (2000).

To compensate for greater chewing forces, the jaw may grow not only vertically but also laterally or medially. While these dimensional changes were outside the scope of this specific study, they need to be taken into consideration by selecting implants of adequate width. The technique of leaving parts of the base plate outside bone is limited to areas where the buccal soft-tissue structures are not overly thin or consist of thin attached gingiva, since those tissue types may cause mucosal penetration of the projecting implant. This approach is also useful for early detection of overload osteolysis – i.e. once the implant is slightly mobilized, the patient will notice mild pain during occlusion and, which will give them an opportunity to contact the implantologist in due

course. This type of non-bacterial mobility is usually reversible, particularly in areas of biomechanical stress and if treated in a competent and timely manner.

Likewise, bone is capable of adapting to functional alterations by changing its degree of mineralization. Research in crestal implantology is solely focused on achieving “osseointegration”, while ignoring the fact that major solid bodies (such as long implants or extensive implant-restoration systems) integrated into bone segments that are subject to natural flexion and whose flexural behaviour is different from that of bone will either not be osseointegrated over their entire surface or will involve different degrees of bone mineralization along the interface.

Since the human body lacks true reference points, orientation in longitudinal measurements is difficult. Enossally anchored (osseointegrated) BOI implants can change their position relative to the radiographically visible boundaries of the jaw as the bone morphology changes due to functional influences. Basal plates inserted in the distal mandible tend to migrate upwards in a cranial direction relative to the lower edge of the mandible. This upward migration is theoretically opposed to the chewing force, whose tendency is to push the disk towards the caudal aspect. It appears that the steady force of trajectorial remodelling is stronger than the periodic influence of mastication. Installing force-transmitting surfaces in the enossal space and immobilizing them relative to each other by prosthetic means will create relative reference points,

On the one hand, the mastication surfaces guide the muscles; on the other hand, the muscle function thus modified has an effect on the trajectorial architecture of the bone structure and implant bed.

The bone must therefore be given an opportunity to change its morphology in order to adapt and to re-orient its trajectory. The growth tendencies in crestal direction must not be thwarted by the presence of pontics. In our experience, contact between pontics and mucosa may gradually give rise to pain (frequently at a subconscious level) and avoidance patterns. This may prevent uniform mastication, thus jeopardizing the integration of implants, or give rise to excessive loading.

In addition, contact between pontics and mucosa will keep the bony structure of the jaws from developing their most favourable biomechanical shape. This, too, may cause problems in the implant bed. For example, growth may occur in directions other than the biomechanically favourable crestal direction (e.g. in width). In the worst-case scenario, the load-transmitting surfaces may lose their cortical contact. Since morphological changes of this type can never be excluded with certainty, BOI implants should always be inserted such that they tend to

project from the cortical bone rather than being located in a deeper position.

In advanced distal ridge resorption, where enough bone volume is present in the anterior segments to anchor a fixed restoration, it may be advisable not to insert the definitive restoration right away but to adopt a wait-and-see strategy following distal implant placement until the upward migration of the implant associated with vertical bone formation has been completed. Bone apposition might be greater if no masticatory forces are present to counteract it. Furthermore, this would theoretically reduce the need for subtractive adjustments to the restoration.

If the lingual aspect of the residual ridge is very high but narrow, the threaded pin can be placed laterally to the ridge. This will create about the same spatial relationship as if the ridge were strictly growing in a cranial direction after implant placement. In these situations, our approach is to disrupt the trajectories of the residual ridge from the alveolar crest down to the basal mandibular segment by means of a vertical osteotomy created with a tungsten carbide cutter mesial to the implant site. This increases the functional stress on the implant osteotomy, which, in our experience, will accelerate healing and thereby improve the chances of successful integration of the implant. If this osteotomy is not performed, the risk of integration problems is higher because the bone will lack the functional stimulus to close the lateral osteotomy.

Functionally induced build-ups of vertical bone mass in the mandible have also been discussed in connection with transmandibular implants (TMI) (Bosker et al. 1991). This type of build-up appears to depend on the presence of greater chewing forces acting on the bone from enossal direction as a result of restored function and on the absence of infection-related bone collapses where the implants penetrate the mucosa. Therefore, the transmucosal vertical implant surfaces must not participate in load transmission; also, they have to be polished to high gloss. Thus, while TMI and BOI implants rely on the same principle for load transmission, the handling of BOI implants is simpler.

For several reasons, patients who have previously worn a denture will benefit more from new bone formation than patients who had not previously worn a restoration in the edentulous area. For one thing, the initial situation is less favourable as the disuse atrophy of the edentulous ridge is compounded by denture-induced resorption. Apparently, the atrophy is partially reversible. Moreover, chewing forces will decrease in patients wearing dentures as a result of avoiding pressure-related pain. The chewing forces can therefore be expected to increase after a fixed restoration has been inserted. Once the denture is no longer worn, the compressive forces acting on

the mucosa, thus giving rise to chronic ischemia of the crestal mucoperiosteum, are reduced (Mercier and Vinet 1983). The blood supply through the central mandibular artery is reduced in advanced mandibular resorption (Bradley 1975).

Atkinson et al. (1977) demonstrated different regional bone densities in pigs, dogs and humans following tooth extraction. Bone density in areas exceeding the alveoli would also change in a second phase of remodelling. In the initial phase, the density would decrease due to a greater degree of porosity. The tunnelling secondary osteons (BMUs) would induce bone remodelling even in the areas surrounding the alveoli. After initial healing, resorption was observed in the area of the extraction socket. Resorption was delayed if crestal implants had been inserted in the area of the alveolus, and bone density was found to be increased; in fact, bone density would sometimes even rise above the baseline level. Nine months after implantation, resorption processes adversely affecting the preservation of alveolar bone were seen in the implant area. On balance, the experiments performed by Atkinson et al. yielded no evidence of any changes on the lingual side of the mandible following insertion of crestal implants, which is in keeping with our own findings obtained previously with healed but unloaded dental implants in dogs.

Both tooth extraction and the insertion of metal implants will stimulate bone remodelling. Tooth extraction gives rise to disuse atrophy, which the implantation procedure is designed to avoid.

Following the extraction of mandibular molars, the load-transmitting line of the mandible, usually located along the vestibular aspect, may travel to the lingual aspect and take a cranial rather than lateral orientation. Thus, in patients with intact dentitions, the molars prevent the force-transmitting line from establishing its ideal distomesial orientation. In patients with deep mandibular periodontitis, the force-transmitting lines become dislocated despite the presence of teeth, which will ultimately cause those teeth to be lost.

Nonetheless, the principal force-transmitting structure of the mandibular bone will still remain unchanged if premolars are extracted or replaced by implants (Atkinson et al. 1977).

There are numerous indications in the literature that load-related stress in the mandible (e.g. by muscle attachments and other functional mechanisms) will influence bone growth. Growth is reduced if muscles are removed (Moore 1973). By removing them unilaterally, the direction of growth can be modified (Schumaker and Dokladal 1968). Tooth eruption and the sheer presence of teeth will influence bone remodelling and, hence, bone structure (Zengo et al. 1973).

It has been known for a long time that bone fractures healing in a curved position will straighten out over the years (Jansen 1920; Basset 1965). Frost (1964) postulated that the bone reaction does not primarily result from compressive and tensile forces but from the tendency of the force acting on the bone to change its curvature. In his theory of flexural neutralization, he summarized that increasing concavity gives rise to bone apposition, whereas increasing convexity gives rise to bone resorption. This may be one reason for the sharp increase of vertical bone volume observed in the distal mandible after replacing dentures. The curvature is thus reduced.

9.3.3

Clinical Application

The experience with BOI-based implant-restoration systems underscores the extraordinary importance of a competent follow-up protocol. Particularly in the first 2 years following surgery or prosthetic treatment (initial treatment or re-treatment), the relative migration of the basal disk may give rise to significant premature contacts. For this reason, subtractive occlusal adjustments need to be conducted periodically and in a timely manner. The extent of this requirement is greater than dentists who are inexperienced when it comes to BOI implants would normally consider to be necessary based on their experience with natural teeth or crestal implants. It is frequently necessary, for example, to extend subtractive adjustments down into the metal framework. In patients with occlusal deformities, it is usually necessary to rebuild all masticatory surfaces several times as functional blocks are increasingly being resolved over the course of treatment. We use bonded composite for this purpose, since this material can be readily added to porcelain surfaces.

Further investigations are needed to examine morphological changes of the maxillary bone as a result of increasing functional stimuli. Clinical experience has shown that pontics in the maxilla will routinely call for basal adjustment as well. Lever forces pushing the pontics against the mucosa and ridge may cause implant loss. In our experience, the situation is somewhat different in the maxilla. The macrotrajectories in the distal maxilla tend to orient themselves towards the target points of the distal muscles. Therefore, the distal BOI disks are more likely to lose their vertical dimension and sink into the bone in a caudal direction. The resultant premature contacts in the anterior segment of the maxilla may give rise to undesirable extrusive forces acting on the posterior BOI implants.

If the masticatory surfaces following mandibular implant placement are not adjusted in due course,

the mandible will suffer damage if a stable natural dentition is present in the maxilla. By contrast, if BOI-based implant-restoration systems in the maxilla are associated with poor bone quality and quantity, damage will more likely be inflicted in the maxilla in the form of overload osteolysis or implant fractures.

In patients with periodontal disease who originally presented with mobile teeth, BOI implant treatment tends to result in continuously increasing masticatory forces, reconfiguration of the occlusal plane, and extensive bone remodelling. In our experience, these patients therefore require especially close monitoring and even more occlusal adjustments than usual.

One of the patients with consistently dissimilar chewing patterns maintained her strictly unilateral chewing pattern for approximately 2 years following treatment. Also, the onset of vertical bone gain on the resorbed side of the jaw was considerably delayed in this patient. In fact, the process of vertical bone gain was not initiated until a balanced chewing pattern had been attained, suggesting that the changes in bone structure were not (only) due to postoperative modelling-related subperiosteal increases in vertical bone volume.

In extreme cases of distal mandibular resorption, it may be useful to take advantage of functionally induced new bone formation by employing a two-step implantation technique (Figs. 9.27, 9.28). After all, a BOI implant at the position of the second molar cannot be inserted unless a minimum vertical bone volume of around 2 mm is available. In that case, a more distal position along the ascending ramus can be selected. One should consider that implants in this position may not be acceptable in the long run, both because they cannot be accessed with oral hygiene instruments and because the bone and soft tissues tend to overgrow the implant site. The same is true of the soft-tissue structures of the lateral cheek area as they move in anterior direction. The patient needs to be informed of these eventualities. Despite any chronic inflammation arising from such overgrowth, the long bridge span between the canine area and the distal implant will soon reveal abundant growth of vertical bone volume, thereby enabling a secondary procedure to insert the implant at its most desirable site. The old bridge and the new implant are best connected by an overbridge. The plate of the first implant can be either removed or left in place in the second procedure. We generally prefer to leave it in place, thereby keeping the cortical bone structures largely unchanged and minimizing the extent of bone remodelling.

It is sometimes difficult to convince patients that abrasive basal adjustments of the pontics are really necessary, since an impression of unnecessary damage to the bridge may be created. The patient has

to be informed of this necessity in a sensitive manner, so that the required treatment can be performed and arguments are avoided. Also, the threaded pin may sometimes turn out too short in situations of massive vertical bone growth, so that the abutment interface recurrently sinks into a submucosal position. In this situation, the implantologist may first attempt to use TSD55 or TSD44 abutments instead. If the dilemma is still not solved, one might consider reducing the bone extensively via a crestal approach.

9.3.4

Summary

The shape of the mandibular ridge may change after BOI implants were inserted, involving vertical bone gain both below and above the load-transmitting basal plate. The bone generated above the basal plate comes to be located on the lingual side of the edentulous mandible in accordance with the principal trajectories. Thus formation of new bone mainly takes place lingually to the threaded pin.

The extra bone volume routinely formed below the basal plate is capable of raising the implant and the prosthetic structure relative to the occlusal plane. It is therefore necessary to perform subtractive occlusal adjustment on the basal surfaces of the pontics and the occlusal surfaces at regular short intervals for at least 2 years following implantation. Decompression of the TMJ (e.g. when the denture is no longer used) or a relative elongation of the mandibular ramus may conceivably occur as a counterpart to the upward migration of the prosthetic structure.

Since vertical bone apposition is also to be expected in the areas between the implants, the pontics should always be integrated with some clearance. If contact with the crestal mucosa is established as the bridge is worn, the pontics need to be reduced via a caudal approach, as the endpoint of vertical bone growth is not known.

Studies performed on humans and animals have consistently demonstrated that vertical bone formation does indeed take place. Animal experiments have additionally shown that lingual bone apposition also takes place, possibly as a result of osteotomy-related plastic remodelling of the mandibular ridge for curvature and bone volume compensation.

Since modifications to the restoration must be expected after any changes in chewing function, these changes will also involve morphological adaptations of the bone. This, in turn, may have consequences for the position and loading of BOI implants. BOI-based implant-restoration systems will stabilize within 1–3 years. The type and extent of morphological changes during this period will depend on the difference between preoperative and

postoperative function and on whether a removable restoration had been worn previously.

Since the uniform use of the prosthetic structure (i.e., a stable symmetrical chewing function) influences bone formation, it is reasonable to assume that prosthetic modifications performed on implants that have already healed will have far-reaching consequences in terms of bone morphology. Therefore, patients in whom a new restoration was placed on existing implants need to be followed up closely by a competent implantologist for another 2 years.

Generally speaking, a threaded pin of maximum length should be selected for BOI implants, based on the interocclusal dimensions. This will prevent the restoration-bone or restoration-mucosa interface from being overgrown by bone or mucosa even if vertical bone apposition is extensive.

If the vertical bone volume at the site of the second molar is inadequate, an alternative method can be adopted in which an implant is first placed in the lower segment of the ascending ramus, followed by inserting a fixed restoration to stimulate functional bone apposition. The distal implant can later be replaced with a more anterior BOI implant. The load-transmitting disk of the first implant is normally left in place with this strategy.

Based on BOI implants, fixed restorations can even be inserted in situations of extreme ridge resorption. However, the surgical and prosthetic measures required for this purpose will interfere substantially with the biomechanics of the masticatory apparatus. Due to the extensive morphological changes in the jawbone, adjustments to the prosthetic restoration need to be made on a regular basis.

Implant-restoration systems based on BOI implants presumably differ from those based on crestal implants with regard to the nature and extensiveness of the follow-up protocol (Besch 1999). Good patient compliance is indispensable if a stable outcome is to be achieved. The name «basal osseointegration» procedure is self-explanatory against the background presented in this chapter. The technique of «osseodistraction» aimed at increasing the vertical bone volume is not indicated in the distal mandible because the required bone volume will be established spontaneously after BOI implants have been put into prosthetic service in an adequate and symmetrical manner.



Fig. 9.25. Double-disk BOI implant with a crown block restoration. The old cortical bone line is clearly visible. Lingually, there is new formation of woven bone. The connective tissue in the shaft area extends below the crown, and there is no epithelial growth in a caudal direction. The soft-tissue structures around BOI implants do not seem to have a layered structure (biological width) like the one described with crestal implants. The implant has been treated by shot-peening for a smooth uniform surface

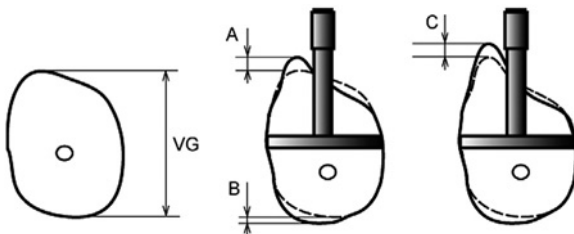


Fig. 9.26. Outline of bone remodelling around a BOI implant in the distal mandible. Left Initial shape of the resorbed mandible; centre situation at 12 months after BOI insertion; right situation at 24 months. Each interrupted line indicates the shape of the adjacent drawing to the left

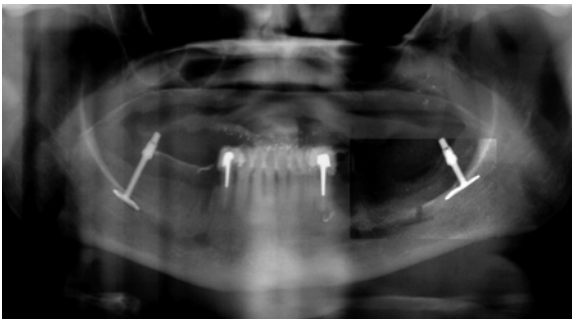


Fig. 9.27. Situation after insertion of the "first" implant at 38. The vertical relations are such that an implant with a higher G value could not be selected. The T-slot of the original implantation attempt at 37 is still visible. That attempt had failed because the mandibular canal was located too far crestally. Infranelar implantation failed because of the overly lateral position of the canal

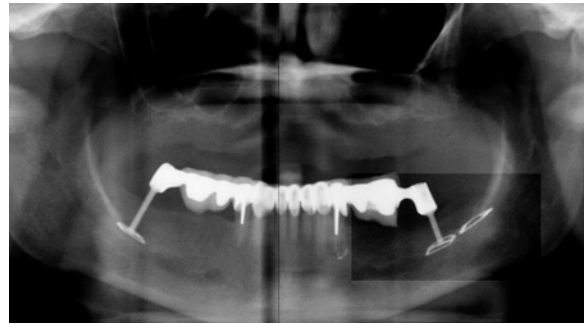


Fig. 9.28. The same patient 21 months later. The second implant had been inserted 15 months after the first one. The first bridge was connected with the new implant via an overbridge. The threaded pin of the first implant at 28 was removed; the plate was left in place. Vertical reduction of the newly formed bone is not a useful option in these cases because the bone would be growing back again



Fig. 9.29. It is not recommended to line the bridge with a wide base of metal, since it would be very difficult to reduce and repolish this material when vertical bone growth occurs if the need arises. Likewise, there is hardly any space left to access the base with oral hygiene instruments

9.4

Hormonal Influences and Drug Treatment

9.4.1

Effects of Hormonal Deficits

Osteoporosis offers a chance to study the nature and extent of hormonal influences on bone behaviour in a borderline situation. The bone-marrow spaces within the bone expand in this disease, i.e. bone resorption takes place from the inside. The trabecular structures are weakened. If bone is functionally induced to increase its volume, the apposition processes will take place on the outside of the bone. The affected bone structures will become thicker. Bone training is the only useful long-term treatment for osteoporosis, although drugs that will increase the degree of mineralization (e.g. Fosamax) may be needed as well so that exercise without incurring bone fracture becomes possible in the first place.

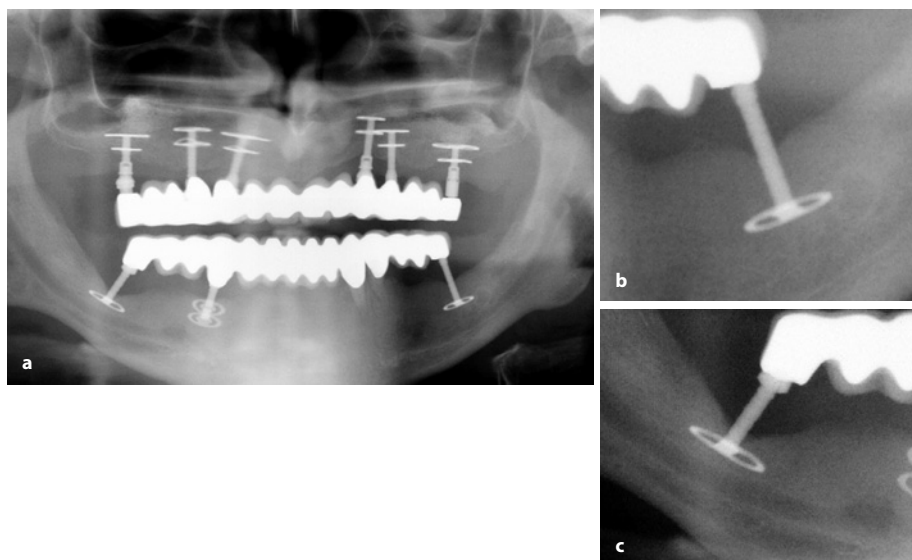


Fig. 9.30a–c. Even though the modelled bone or the seemingly missing bone above the disk is no longer present, implant survival is still not in jeopardy. A crestal implant would have been lost by this time (i.e. 9 years after the implant procedure) due to its lack of basal anchorage. Whether the bone structure located crestally to the disk is preserved will essentially depend on masticatory function, preferred working side, masticatory forces and – less importantly – on oral hygiene, local immune status and the surface structure of the threaded pin. Crestal bone loss was favoured by the surface structure of this older implant. If a unilateral chewing pattern is present (this specific patient had a preference for the left side), tensile trajectories will increasingly form on the upper margin of the non-chewing, which are less resistant to resorption than the compressed bone structures on the upper margin of the working side. The bacterial attack (a disk implant with a surface-enlarged vertical implant element was used) has won out over the bone's growth tendencies; also, this patient might have had a laterally unbalanced chewing pattern promoting the resorption of bone on the right side of the mandible

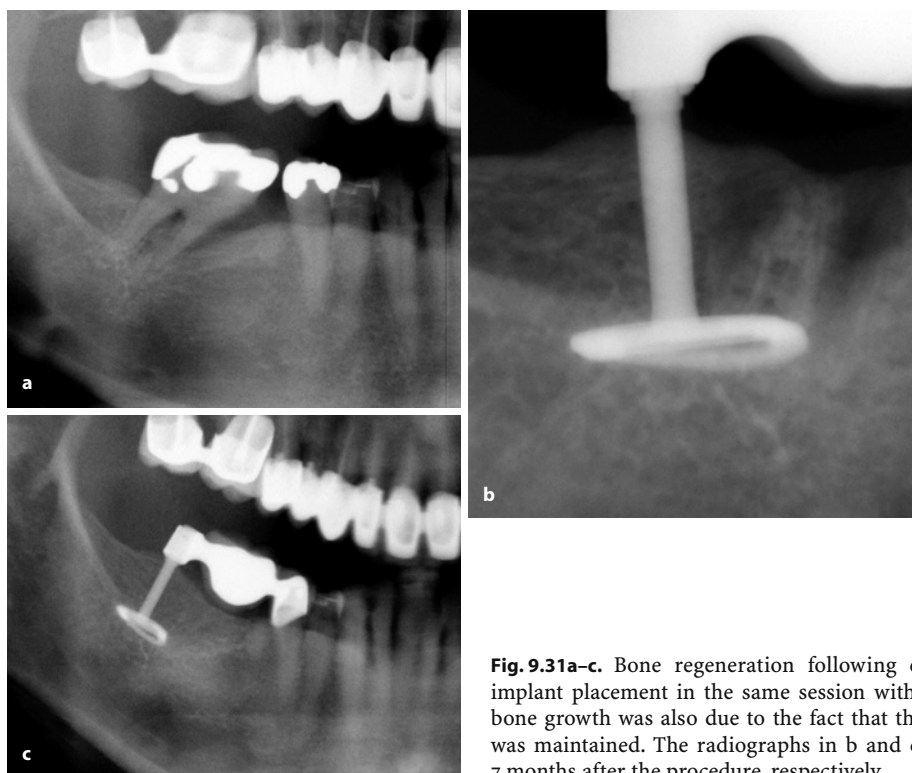


Fig. 9.31a–c. Bone regeneration following extraction of tooth 47 and implant placement in the same session with immediate loading. Vertical bone growth was also due to the fact that the preferred left working side was maintained. The radiographs in b and c were obtained 4 weeks and 7 months after the procedure, respectively

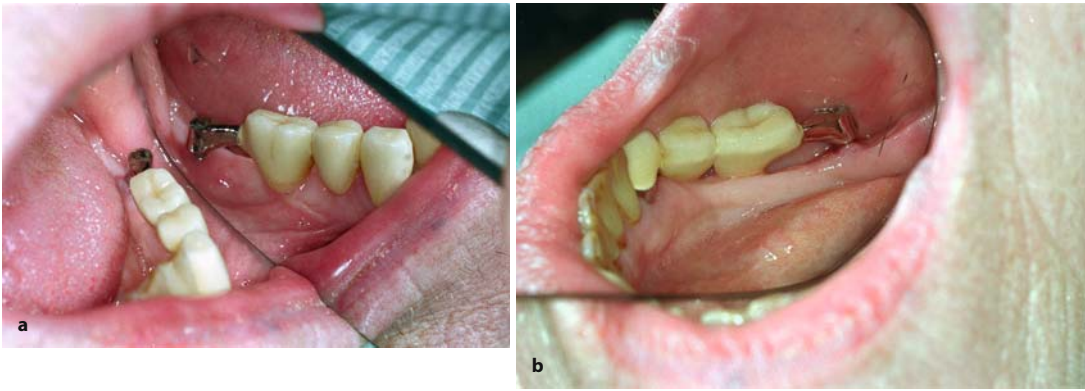


Fig. 9.32. **a** Situation 3 years after implantation. The initially visible threaded pin is now covered with bone. Only the abutment emerges visibly from the bone. The transitional zone between abutment and threaded pin is populated by bacteria, which prevent the bone from growing further. **b** Lingual view. Lingually to the pontic, there is enough space for functionally induced vertical bone growth



Fig. 9.33. The pontics of this bridge are extended caudally much too far. Contact with the mucosa will be established soon. Once this line has been crossed, the bridge will either be dislodged from one of the abutments, or the abutment (i.e. the residual tooth structure or implant) will fracture. Once the functional contact to the bone has been established, the incentive for bone growth will be even greater. This may give rise to problems very soon unless subjective adjustments are made on a continuous basis



Fig. 9.34. Vertical bone growth may give rise to extensive pressure sores below pontics

When serum calcium levels are falling, parathyroid hormone is released that will stimulate osteoclasts to induce bone loss, so that calcium is released into the circulating blood. By the same token, calcitonin is released when calcium levels are high, so that the process is reversed. In other words, osteoporosis develops when the equilibrium shifts in favour of resorption. Today the equilibrium can be influenced by drug treatment. Drugs such as Fosamax will improve calcium deposition by adjusting the calcium balance.

In order to preserve the mechanical stiffness of the bone despite the volume loss caused by osteoporosis, the degree of mineralization of the remaining cortical bone is increased. This explains the brittleness and the comminuted fractures

observed with osteoporotic bone. It does not explain, for instance, the poor healing tendency in femoral head fractures. While these hormonal influences do have a sustained long-term effect, they have no effect on acute bone trauma, as the cascade-style repair mechanisms are triggered and maintained mostly by local factors. The poor healing in osteoporotic fractures has less with hormones to do than with the low bone volume and the minimal overlap and contact surface of the bony ends of the fracture (e.g. femoral head), while the residual cortical bone structure is characterized by a high degree of mineralization and a weak blood supply. In femoral head fractures, the problem is compounded by the relatively great propensity of the fracture ends to become dislocated against each other. Therefore,

the preferred method today is to incorporate a hip endoprosthesis rather than immobilizing the femur and the rest of the whole body. The latter approach, which used to be state of the art for a long time, would leave the entire organism immobilized for too long, thereby promoting generalized osteoporosis even further.

The newly formed bone in the defect area shows a smaller density of secondary osteons while the number of BMU activations is higher. In other words, the traumatized bone becomes «younger» and more elastic. As an undesirable consequence of this rejuvenation, however, the elasticity differential between the preexisting osteoporotic bone (Burr et al. 1997) and the elastic new bone is so great that the healing progress will unfold very sluggishly. Frequently, it takes several more fractures in the same area to bring about exostosis-style ossification and abundant bone formation.

9.4.2

Fractures After Implant Therapy

Patients with hormonal deficiencies in bone strength have a greater risk of jaw fractures due to crack propagation on immediate loading. These jaw fractures occur predominantly in the mandible. Peri-implant fractures with crestal implants will always necessitate explantation. After all, such fractures will invariably occur along the vertical implant axis whose surface is micromechanically roughened, thereby promoting infection, in addition to the fact that crestal implants have no additional stabilizing components such as disks and rings. In jaw fractures near BOI implants, the spectrum of applicable treatment options is broader.

Patients with pronounced osteoporosis are liable to incur spontaneous fractures, notably in the distal segments of the mandible. These fractures occur usually symmetrical. That is to say, after the first side has fractured, the contralateral side will soon follow suit.

The fact that these fractures only occur after about 6 weeks is due to the increased porosity in this phase of bone remodelling induced by changes and improvements in function. Truly stable areas become increasingly smaller, so that the stresses will ultimately increase to the point of fracture. With BOI implants, the load-transmitting implant segments are already well integrated when jaw fracture occurs along the threaded pin (i.e. the most debilitated jaw area in the initial phase of remodelling). Thanks to this integration, additional therapy is usually unnecessary, provided that the prosthetic superstructure is already in place to serve as a splint. In our view, the importance of immediate loading in osteoporosis patients cannot be overstated. In the

rare event of BOI-related bone fractures, the fracture will always occur vertically along the threaded pin because this is the weakest area. Ossification in the disk areas is, by contrast, always intact even though the hormonal situation may be unfavourable.

The tendency of the crestal bone to grow towards vertically can be observed in an exemplary manner after hormone-related fractures in the distal mandible. Bone modelling and remodelling is strongly stimulated by this type of fracture, and morphological changes will develop faster than in the absence of fracture. Therefore, the bridges have to be periodically reduced along the basal aspect. Fractures in the area of premolars (e.g. in structures with anterior support only) usually remain unilateral. Modifications of the lingual curvature of the mandible are therefore likely. If the fracture is followed by extensive bone apposition, the premolar implants may lose their lingual cortical anchorage. These cases have to be closely monitored, and the affected implants may need to be replaced with larger ones in terms of disk diameter. The bridge can normally be reused.

Fractures in the maxilla are relatively rare with BOI implants. One case that occurred in our practice was apparently due to the use of a spring accelerator (Crown Click) to remove the bridge. This fracture encompassed the entire alveolar ridge in the distal maxilla along with the integrated implant. Subsequently, the chewing forces led to a slight anterior dislocation of the bridge, and the fractured bone segment rotated by around 20 degrees in a vestibular direction. We were not able to verify whether the distal bone block slid away in an obliquely lateral direction along the stable anterior segment of the maxilla or whether the rotation was due to the continued presence of a distomedial attachment (e.g. in the area of the chewing muscles). Further treatment consisted in placing additional anterior implants. After that, all structures (i.e. all implants, the new bridge, and the fractured bone area) stabilized.

Osteoporotic jaw fractures after insertion of BOI implants cannot usually be verified by radiography, as there is hardly any space left for dislocation due to the comminuted nature of the fracture and the implantological splinting. Also, the fracture ends will interlock immediately. While a single BOI implant can per se provide effective splinting, this effect is even more pronounced when the bridge is in place. More importantly, the bridge will prepare the ground for normal jaw function to be re-established. The patient should stick with soft food over 2–4 weeks. Antibiotic coverage is unnecessary in our experience. The pronounced modelling may give rise to strains, distensions and reddening at the fracture site. These symptoms are not to be confused with those of bacterial inflammation.

In the event of intraoperative jaw fracture, the dentist may choose to leave the implant in place and use mini-plates for splinting. The issue of immediate loading needs to be carefully reconsidered. If acceptable masticatory function can be attained, it is certainly preferable to incorporate a metal-reinforced bridge as soon as possible for effective splinting.

Bone covers over implants can be left in place on fracturing but need to be immobilized (e.g. with osteosynthesis screws).

In the wake of jaw fractures, any associated implants may fracture too, as the peripheral surfaces of the integrated disks will move relative to each other, together with the surrounding bone structures. This will create tensions inside the implant fixture that – either by themselves or in conjunction with the masticatory forces – may exceed the range of elastic reversible deformation of the implant. Since implant segments that have undergone plastic deformation are more rigid (less elastic) than non-deformed segments, they are less resistant to variable flexural loading. The reader is referred to Chapter 21 for a more detailed discussion.

9.4.3

Fractures and Osteomyelitis

Crestal implants have large mucosal emergence points and rough surfaces. This combination will promote infections. Unlike natural teeth, implants have no transitional areas consisting of soft tissue (e.g. periodontal ligaments), so that any deep infections will quickly give rise to osteomyelitis. For fractures of the entire mandible to occur, however, additional factors must come into play, such as hormonal deficiencies and low blood supply to the affected bone area, combined with high loads and/or heavy remodelling. If implants and prosthetic superstructures are inserted in situations of advanced ridge resorption, there is always a chance that functionally induced morphological changes will give rise to extensive remodelling of the entire jaw. It must be borne in mind that this mechanism may be all that is required to cause osteomyelitis in the presence of bacterial invasion. In our experience, problems of this type are not an issue with BOI implants, given the small diameter of their mucosal emergence point and their smooth surface offering unfavourable conditions for bacterial retention. We must add that our experience is largely confined to external-thread BOI designs with a diameter of less than 2 mm at their mucosal emergence point.

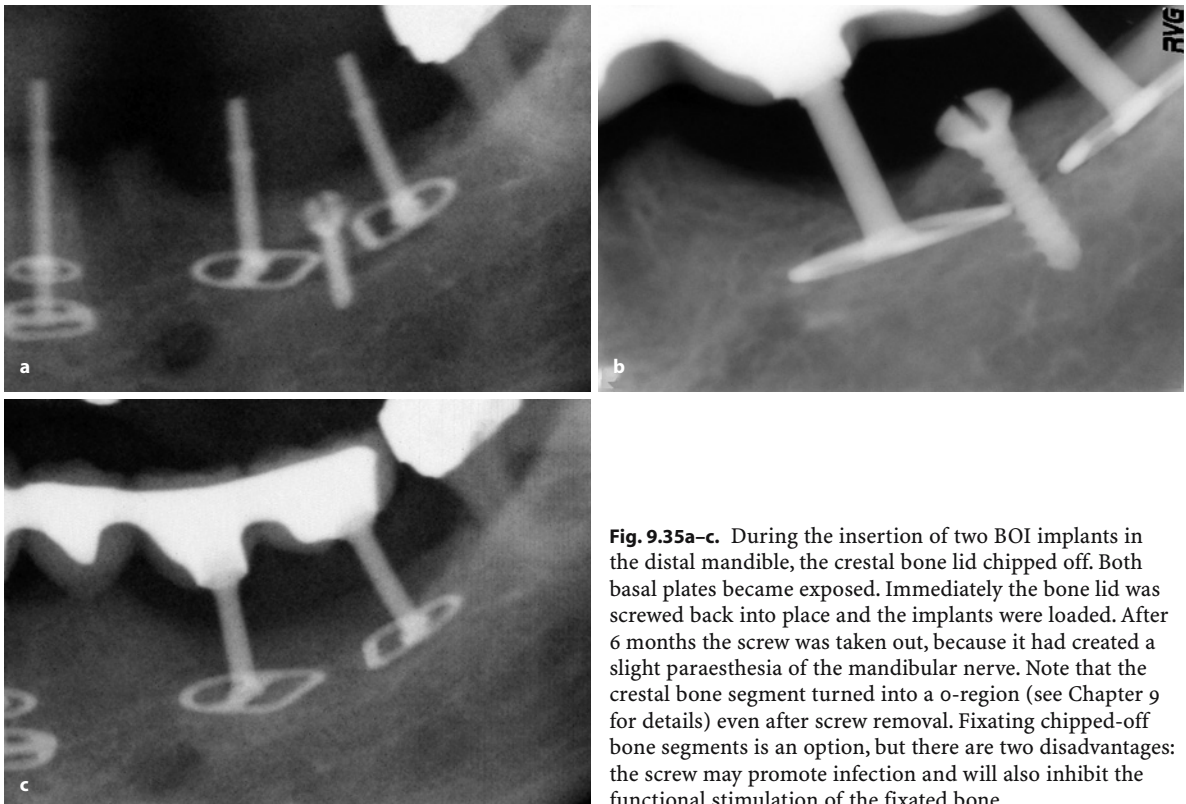


Fig. 9.35a–c. During the insertion of two BOI implants in the distal mandible, the crestal bone lid chipped off. Both basal plates became exposed. Immediately the bone lid was screwed back into place and the implants were loaded. After 6 months the screw was taken out, because it had created a slight paraesthesia of the mandibular nerve. Note that the crestal bone segment turned into a o-region (see Chapter 9 for details) even after screw removal. Fixating chipped-off bone segments is an option, but there are two disadvantages: the screw may promote infection and will also inhibit the functional stimulation of the fixated bone.

9.4.4 Psychosocial Aspects

It is important to realize that diseases of supporting tissue are a major issue in medicine. Osteoporosis is today the most common bone disease in industrialized countries. Preventive measures to avert damage to the supporting bone structures, including physical exercise to build up and strengthen the muscles, have become widely accepted.

The human jaws are continuously subjected to great loads, almost regardless of how well the muscles are trained. Even a movement such as wide mouth opening is associated with massive torsion both in the maxilla and in the mandible.

Patients with osteoporosis need to explore what loads they can tolerate from a mechanical standpoint and strike a balance between stress and rest. Having incurred multiple bone fractures in the past, these patients have usually developed a deeper understanding of their disease and are more receptive to conservative treatment techniques in the aftermath of fractures. BOI-based solutions offer considerable advantages over crestal implants in this situation. For patients with osteoporosis, bone fractures are a common and familiar event. Therefore, the eventuality of jaw fractures in the wake of implant procedures is also a «normal» thing to expect for them. The dentist can therefore easily adopt the wait-and-see strategy and conservative treatment discussed above. In advanced ridge resorption, the dentist is more likely to select a conservative approach anyway (Barber 2001), given

the reduced blood supply and the high risk of infection in this situation. The risk of osteomyelitis is significantly greater if the fracture is exposed for treatment. We need to remember that the functional tissue conditions along the polished vertical surface of the threaded pin will have stabilized by this time to the point of matching the physiological state of a closed mucosal structure.

9.4.5 Conclusion

Osteoporotic fractures of the jaws after placement of BOI may be a consequence of a positive feedback between damage accumulation and the increased remodelling space associated with the repair. Hence fractures usually occur 6 weeks after implant placement. The bone around the load-transmitting base plates is at this stage of healing already well attached to the base plate and has healed initially. The fracture usually occurs in the region below the treaded pin. Treatment of this event should be a conservative one and patients with known osteoporotic disease should be treated in immediate load. This way the stabilizing bridge is installed well before the expected fracture takes place.

Improving the quality of bone through medication with bisphosphonates (e.g. Fosamax) is an option in case that osteoporotic tendencies are known preoperatively.

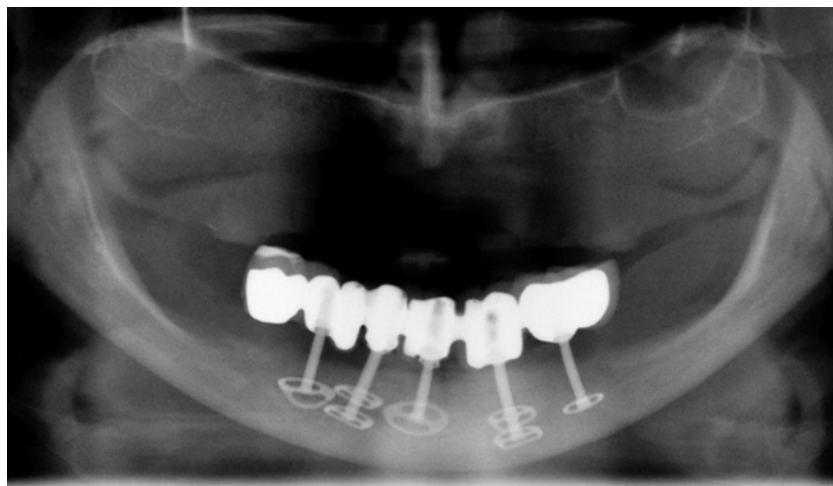


Fig. 9.36. Approximately 6 weeks following insertion of a fixed bridge on five BOI implants, the mandible fractured in a paramedian direction around the area of tooth 33, at the point to which the threaded pin of the double-disk BOI implant would extend. Since the bridge had already been inserted, no immediate therapeutic action was required. During the healing process plastic deformation of the mandible occurred, with appositional remodelling as a consequence. This changed the curvature around 44, and the BOI implant 7G8 ED originally inserted here lost its contact with the lingual cortical bone and became instable. It was exchanged for a wider 9G8 ED implant. The bridge did not have to be replaced

9.5 Macroscopic Functional Anatomy

Looking at a bone is looking into the past

9.5.1 Introduction

While the influence of function on form, as relating to bone structures, has been widely discussed in the scientific community, these mechanisms are largely ignored in clinical dental practice. Solid basic research is in short supply today, as third-party funding of scientific investigations has unfortunately become all too common. In addition, animals for experimental studies are no longer readily available. Since there is scarcely any return on the time and money going into basic research, studies of this type will only be performed if massive personal interests are involved. Luckily, we are in a position to draw on a relatively solid base of scientific data collected in the second half of the twentieth century.

Numerous experimental studies have demonstrated that bone growth in the jaw is influenced by load-related stresses (e.g. by muscle attachments and other functional mechanisms). Growth is reduced if muscles are removed (Moore 1973). By removing them unilaterally, the direction of growth can be modified (Schumaker and Dokladal 1968). Tooth eruption and the sheer presence of teeth will influence bone remodelling and hence bone structure (Zengo et al. 1973).

Washburn (1947) observed various types of skeletal asymmetries after partial removal of the zygomatic arch without damage to the masseter muscle in 1-day-old rats. Similar alterations on removing the masseter muscle were obtained by Horowitz and Shapiro (1955). Nanda et al. (1968) investigated the effect of relocating the distal attachment of the masseter muscle in 1.5-month-old terriers on jaw morphology after another 7.5 months. The morphological differences relative to the contralateral normal side turned out to be very small. This finding may be due to various factors. For one thing, the relocated chewing muscles had become considerably smaller and thus weaker. In spite of that, midline shifts towards the treated side were seen that originated around the premolars. These results cannot be directly translated to humans, as dogs have a strictly vertical chewing pattern. Their condyle function is confined to pure hinge axis movements; in fact, their very tooth morphology is designed for vertical chopping movements only. Nevertheless, the lower margin of the mandible features an antegonial notch, such as the one that is sometimes clearly visible in OPGs of human mandibles as well. It

appears that the anterior margin of the masseter muscle is more active in these individuals than the distal muscle portion. After all, both muscle segments are separate anatomical and functional entities (Eschler 1952). Generally speaking, bone growth is likely to decelerate after muscles have been separated (Avis 1961).

9.5.2 Age-Related Changes in Jaw Morphology

Once growth has been completed and the mandible has reached its maximum size, usually a process of resorption and remodelling is gradually initiated. During this phase, the porosities inside the bone acquire an uneven distribution, and bone morphology develops towards the shape we can see in old edentulous patients. This ageing process unfolds in the same manner regardless of whether teeth are present or absent, as the distribution of porosities is equal in both cases (Atkinson and Woodhead 1968). Bone resorption is always stronger buccally than medially. Up to around 35 years of age, the porosity of the mandible remains constant. After that, it keeps decreasing for around 10 years and then increases again later in life (Manson and Lucas 1962). The higher bone density between the ages 30 and 40 might also have to do with the higher prevalence of periodontitis in this age group. Since less porosity is associated with less perfusion and higher mineralization, the structural defence status of the jaw might be altered. While data of this type are not available for the maxilla, the temporal relationships in the mandible are more or less in keeping with the rate of BMU formation (Fig. 9.4). It is therefore reasonable to assume that conditions are similar in the maxilla. Dentulous jaws do not reveal drops in the BMU curve as sharp as the one in Fig. 9.4, presumably because the jaws are continuously remodelled up to around the 30 or 40 years of age due to continuing tooth eruption and changing functional requirements. Since any extraction and implantation procedures will induce new remodelling, it is almost impossible to draw any statistically significant conclusions about the porosity of jaws. Surprisingly, there is no sex-specific difference in porosity. von Wowern and Stoltze (1978) failed to establish any differences between male and female volunteers based on relative bone volume, trabecular structures and BMU activity. They also found that porosities in the mandibles of adults increased in an age-dependent manner. The age of an individual can be estimated quite exactly by evaluation the density of secondary osteons of the long bones (e.g. the femur). This test will not give reproducible results in the jaw bones since these bones are subjects to too many non-stress related

influences throughout the phase during which teeth are present, lost and replaced.

Tooth loss will greatly influence bone morphology, as the bone structure immediately surrounding the tooth will undergo local resorption. The changed utilization pattern of the affected jaw segment will extensively alter the morphology of the entire jaw. The masticatory forces are not always reduced immediately, but they can increase locally to compensate for the tooth loss, or loss of balance (Hylander 1979).

9.5.3

Maxillary Morphology

In individuals with normal chewing function, the pressure of the mandible exerts an obliquely advancing force on the teeth. The cortical bone on the vestibular aspect of the maxilla absorbs these forces like a net. This process stimulates bone growth. As the bone is increasingly compressed in a medial anterior direction, the large bone block of the nasal spine is formed.

This process is graphically illustrated by the finding that extraction of the maxillary canine and complete separation of the maxilla in a vestibulo-oral direction will give rise to the formation of a tuberosity mesially and vestibularly to the maxillary first premolar. Given the speed of new bone formation, only plexiform bone can develop. As the osteotomy area is healing, part of the plexiform bone is resorbed while part of the tuberosity will «travel» farther towards the medial aspect and will eventually merge with the bone in the area of the lateral incisor. This situation gives an impressive demonstration of how large bone volumes are relocated. While the forces acting on single-root teeth such as premolars are virtually always eccentric in nature, molars are more often affected by centric forces that do not necessarily favour mesialization. In addition, maxillary molars will tend to rotate around their palatal root rather than actually migrate in a mesial direction. The lower premolars are more likely to move distally due to their oblique surface contact; it is also for this reason that they usually show an inverse curvature characteristic. The upper premolars do not have this characteristic because they evolved from a uniform bone mass. The lower premolars, by contrast, evolve with the body of the root in the alveolar bone and the tip of the root in the basal bone.

The trajectorial structures of the maxilla are influenced by two major muscle directions: The lateral pterygoid muscle pulls the maxilla in a sagittal direction. The masseter, temporalis and medial pterygoid muscles act vertically and tend to increase bone volume in the anterior part of the maxilla if teeth transmit these forces to the bone. Bone volume

increase in an anterior direction is caused by the mesio-distal inclination of the cusps of the teeth in both jaws. As a result, the anterior nasal spine is created by a surplus of bone which is moved along anteriorly on both sides of the maxilla and piles up apically and between the roots of the maxillary central incisors (Seipel 1958). There is an increase in strain in the alveolar arch and around the rim of the nasal cavity (Gross et al. 2001).

Other age-related alterations in maxillary morphology will be discussed in connection with implant therapy along the maxillary sinus.

9.5.4

The Problem of Symmetry (Which Was First: The Hen or the Egg?)

As explained previously in Chapter 9.3, both sides of the mandible have a tendency to level out in terms of bone volume. This tendency is presumably due to the symmetrical alignment of muscles and the symmetrical innervation of these muscles.

Asymmetrical bone conditions are observed mainly in the mandible, where midline shifts take place after unilateral chewing patterns have been present over extended periods of time. Maki et al. (2001) performed a very informative study based on 32 volunteers (age: 8–30 years) with asymmetrical mandibles deviating by 3 mm or more. They observed that peak mineralization was higher and chewing muscles were larger on the shorter sides of those mandibles. The authors did not discuss the cause of these asymmetries, and they did not break down the exact sites of peak mineralization. Surprisingly, a preferred chewing side was not observed in this group of patients. Perhaps this issue was not addressed specifically enough. It is also conceivable that the forces exerted by the muscles will acquire a bilateral equilibrium in this age group once the asymmetry is fully developed. This finding, in a sense, conflicts with the clinical observation that early development of unilateral chewing patterns (e.g. due to painful or missing deciduous teeth on the contralateral side) will trigger a slight extrusion with rotation of the upper first molar on the non-chewing side, thereby creating a unilateral class-II tendency. If situations of this type are left completely untreated (i.e. not even by active switching of the chewing side or occlusal adjustment of the deciduous teeth), the affected side will be afflicted with crowding and cross-bite tendencies, followed by a midline shift towards the chewing side. The precise mechanisms at work become obscured once the chewing side has shifted several times and the cause-effect relationships are no longer clear. The unilateral Class II tooth relationship will then once again affect the chewing pattern.

9.5.5

Summary: Looking into the Past

The fourth dimension – i.e. the time factor – involves continuous remodelling and hence continuous morphological changes in bone structures. Any infections, periodontal problems and/or extractions have an additional impact. Function is a decisive influence on the formation, maintenance and resorption of bone. Implanted bone segments that will presumably come to be resorbed areas as a result of preexisting or induced functional conditions will lose their supporting properties and become susceptible to infection very soon. Thus weakened, they can no longer fulfil their task of load transmission. Histologic bone sections provide us with a map of remodelling direction. All of these BMUs were preceded, and in effect triggered, by mechanical stimuli. We can see active cell formations on these sections, and we can see that the events by which a given activity was triggered occurred some time ago. It is impossible to retrospectively identify the trigger for specific BMU formations and, at the same time, identify their future direction and endpoints. The reason is, that the investigation itself would be an invasive procedure, which would change the tunnelling of the BMUs under investigation. After all, BMU formations contribute to the uncertainty themselves (similar to Heisenberg's uncertainty principle) by inducing changes in the stiffness and anisotropic properties of the affected bone once they have been triggered. In this way, the observed BMU may either induce further BMU activations, or it may induce its own termination. Which event will occur depends, among other things, on the stiffness in the affected bone segment, on the functional load present during BMU formation, and on the hormonal situation of the bone at large.

By way of analogy, the reader may want to consider our visual image of faraway stars. When the light from these stars eventually arrives on Earth, what we perceive with our eyes actually reflects the reality of a distant past. Ultimately, we can only ever catch a glimpse of the past. The same is true when we look at a bone. After all, what we get to see is only the morphological consequences of the genetically induced, hormonally mediated and functionally directed growth of a bone structure, followed by the phase of functional use with all its external influences, down to the phase of disuse atrophy. Particularly in the jaw area, it is frequently possible to read the approximate temporal sequence of the functional changes and disturbance in the mastication system on panoramic radiographs of partially or completely edentulous patients. The reader is referred to Chapter 10 for a detailed discussion.

9.6

Microscopic Anatomy and Nutrient Supply

9.6.1

Why and How «All Things Are in Flux»

The jaws are supplied with nutrients and blood from different sources. The basal portion of the mandible is believed to be perfused from the periosteum, while the alveolar portion and the teeth, which require considerably more blood, are supplied directly by the mandibular artery. This artery is an ontogenetic necessity. In its absence, the teeth and periodontal structures could not be adequately nourished, since the bone volume is too massive in relation to the feeding properties of blood diffusion only (Saka et al. 2002).

It is not completely understood how the osteonal structures are supplied with nutrients and what conditions are present inside the osteons. The following paragraphs provide a brief review of the literature on this issue.

Petrov et al. (1989) investigated intra-osteonal potentials and proposed a FEM model demonstrating the effects of variable loading on flow conditions inside the osteons. An important factor for flow persistence is the diameter of the osteons, which varies locally (Pfeiffer 1998). Rib osteons, for instance, have a smaller diameter intraindividually than femoral osteons. The flow resistance in femoral osteons is therefore smaller, so that perfusion is adequately supported despite the fact that the femur is subjected to a smaller degree of functional elastic deformation than the ribs. The ribs are considerably dislocated by respiration; these functional movements, which are absent in the femur, support the flow of nutrients. It seems that that bone tries hard to keep any flux within strictly defined limits and that lower perfusion does less harm than exaggerated perfusion. On the other hand, lowered outflow from the bone is harmful in any case.

The heart-driven rhythmical propulsion of blood through the vessels is not a relevant factor in areas as peripheral as bone (Petrov and Pollack 2003). Loginova et al. (1998) demonstrated that increased chewing activity did not significantly alter the periodontal blood supply in patients without periodontal disease but did have a notable effect in the presence of periodontitis. Within 10 min of mastication performed on chewing gums, the blood flow increased by 33%. The pulsation of the blood flow in the rhythm of the heartbeat can be observed for the periodontal ligament gap, but it cannot be observed inside the cortical bone.

The activity of osteoclasts is bound to increase the osmotic pressure inside the BMUs in a significant

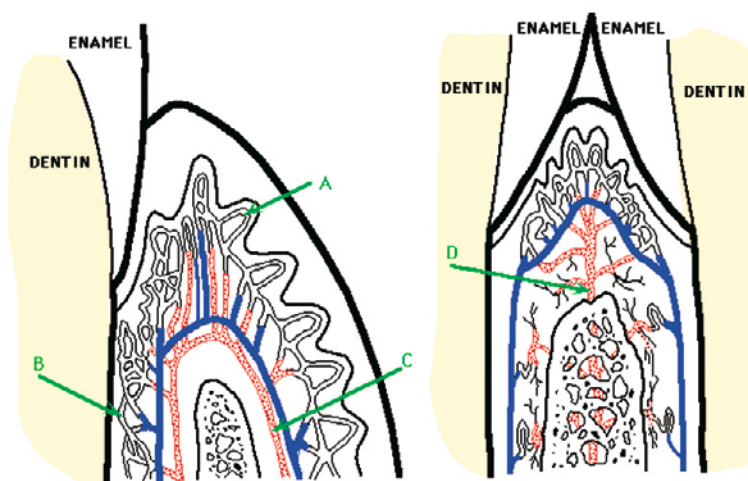


Fig. 9.37. Vessels from the PDL are directly connected to vessels from the oral mucosa. Blood can flow in either direction, depending on the relative pressure between the supply areas

manner. After all, the number of particles and molecules rises sharply while the amount of liquid cannot increase, and salts are not drained either. Presumably, the osmotic pressure inside the osteons is one of the reasons for their proliferation and movement inside the bone. Taves (2002) concluded that the difficulty of cultivating blood cells may have to do with the use of media whose ion concentration matches the one observed in circulating blood. These conditions are not present at the natural site of haematopoiesis. Taves also showed that ion concentrations doubled within the first week of the osteonal life cycle, followed by a smaller increase in the next 2 weeks. After 3 weeks, ion concentrations were 10% below the “normal” level. This period of 3 weeks is consistent with the duration of erythropoiesis. Therefore, other culture systems offering dynamic flow conditions are needed to simulate haematopoiesis in a realistic manner. Botchwey et al. (2003) and Gomes et al. (2003) demonstrated that bone growth was much more effective if three-dimensional matrices were used for culture that allowed flow perfusion from both sides than on flat substrates allowing nourishment from one side only. Around the small basal plates of BOI, perfect suppuration and nutrient supply are guaranteed. Cementoblasts, too, are more effectively cultivated on three-dimensional substrates (Lim 2000). It is well established that the nuclei of osteocytes become pyknotic near non-perforated implant surfaces. Spatial relationships of this type do not apply to BOI implants, since their skeletized design does not seriously affect the quality of flow perfusion. Effective nutrient supply may be one of the reasons why effective load transmission takes place in BOI implants despite the considerably smaller implant-bone interface compared to crestal designs. A combination of two factors might explain this phenomenon. For

one thing, a smaller implant-bone interface might enable a process of internal flow perfusion near the implant, thereby improving the nutrient supply to the surrounding bone structure and enhancing the degree of mineralization. For another thing, a smaller interface will enhance load transmission to the bone, thereby expediting and supporting the maturation of these areas as long as no overload appears. Giavaresi et al. (2003) demonstrated that the contact area at the implant-bone interface was larger with CaP-coated and titanium plasma sprayed surfaces. At the same time, a higher degree of bone mineralization near the implant could only be obtained in crestal implant types with etched or machined surfaces.

Extensive discussions are under way on whether BOI implants may mimic the pulsation of the natural tooth inside the alveolar socket, which are associated with a suction-pressure effect (for details about this idea refer to www.matrix-center.de). This would ensure the presence of microcirculation for the entire life of the implant. Moreover, the perforations in the disk enable blood vessels to grow through the implant. After all, the pump effect induced by the alveoli that generates venous drainage is no longer present once teeth have been extracted. This will ultimately induce bone resorption. The supply vessels (e.g. the mandibular artery) will maintain the requisite overpressure as long as they are not beginning to turn sclerotic. Suppuration slots created by the osteotomy provide an adequate drainage pathway. Even though these slots will close later, in the bone-healing phase, the elastic vertical excursions of the BOI implants can be expected to remain for life.

The mandible and maxilla show a lot of arterial anastomoses. It is in the nature of anastomoses that blood may flow in both directions, as long as no valves are present. The blood pressure within the

peripheral periodontal vessels can become too low compared to the mucosal blood pressure, which may block or inhibit the outflow of blood from these bones. Constant lack of outflow will in turn lead to permanently reduced inflow, causing premature sclerotic degeneration of the mandibular artery. Stasis reduces the nourishment of the jawbone at both ends. This supports also the development of periodontal disease: The unphysiologically increased flow of blood towards the bone from the mucosa and the increase in blood pressure both adversely affect the ability of the periosteum to absorb waste substances coming in from osteons and into the subperiosteal gap. Instead, the periosteal tissues start evaporating liquid, which then forms part of the clinically visible exudate, and harming the adjacent bone by excess oxygenation. A reversal of the direction of the blood flow towards the bone, combined with bacterial attack, also leads to granulation of the soft tissues, accompanied by a loss of resorptive properties. The cells next to the bone no longer have the resorptive properties of the former periosteum.

The complex situation, with factors like interstitial/intraosteonal flow, mass transport, preservation of osteocyte nutriment, and the regulation of remodelling activity and the deposit of bone waste outflow are all interconnected (Tami et al. 2002). Current research into bone physiology and osteology has yielded important data on the basic properties of bone, which have been utilized in the clinical application and development of basal osseointegration for a long time without being aware of the physiological background (Kjær 1994). We understand that periosteal tissue has the same function as lung tissue: in the lungs, large surfaces are necessary for the exchange of gases, and it does not make any difference to what part of the lung surface the gas is directed. Since the endpoint of secondary osteons can be anywhere on the periosteal surface of the bones, the waste expelled from those apertures must be absorbed at any point. Under these conditions, it would not make sense for the body to connect every osteon to a draining vein: the omnipotent periosteal absorption foil offer better service.

9.6.2

Clinical Considerations

Our preferred cooling medium for the osteotomy procedure is ringer lactate. We suspect that this medium drains the bone less and minimizes the resultant drop in osmotic pressure. The use of fatty solutions to minimize surgery-related trauma also has a long-standing tradition in oral bone surgery. One preparation has been referred to as portio



Fig. 9.38. Original implant design (left) and intraoperatively optimized design (right, removed after 11 years in function). Thanks to the enlarged perfusion holes, the implant became more elastic and better integrated into the viscoelastic environment. Blood flow to the bone areas crestally of the basal plate was improved by this small change in design

magica; it includes cod liver oil as carrier, mepacryl and eugenol. Some users prefer to add an antibiotic such as Terracortril N to the preparation.

Since the peripheral segment of the alveolar crest is assumed to be supplied from a central direction, the implant disk may pose an obstacle to effective perfusion. The initially round “disk implants” introduced around 1983 were equipped with very small bores that would not ensure adequate perfusion. In addition, the surface-enlarged shafts of those designs would promote infections advancing from the crest. Users would therefore modify the implant during the procedure by connecting two round boreholes on each side to form kidney-shaped elongated holes.

Consider also that the implant-restoration system has to stay in an elastic union with the viscoelastic bone structures. Therefore, enough space inside the bone is needed for bony deformations. Strategic implant placement would therefore seem to be the method of choice. This is one of the reasons why we try to avoid sinus augmentation, as these procedures will increase the amount of extraneous material and impede any elastic deformations of the implant and bone in an unforeseeable manner. Even in situations of advanced ridge resorption, there is always enough natural bone to place a BOI implant. In weighing the pros and cons of augmentation, one should always consider that the available bone structure is precisely the bone structure that has survived against all the odds. Therefore, the available bone is also the “best”

bone. It is both optimally located and adequately nourished. One should also consider that the blood supply to the maxilla is limited, as only small arteries supply this area. Furthermore, those arteries are connected through three anastomoses (infraorbital, alveolar superior posterior and alveolar superior inferior arteries), which means that an interruption of one of the arteries will usually not lead to a repair of the affected vessel but to regeneration through a new capillary plexus (Solar et al. 1999).

Bone resorption may be a consequence of over- or undernutrition. In situations of extreme resorption, intrabony blood supply is no longer crucial for the bone. The bone volume that will be available in the long term is mainly determined by the level of nutrition provided by the periosteum. Functional utilization will determine the orientation, rather than the volume, of bone morphology. In case that undernutrition is not followed by a reduction of bone mass, fatty degeneration may occur. It is generally believed that this condition starts with episodes of bone-cell ischemia followed by structural changes in inorganic elements (Glimcher and Kenzora 1979; Ficat 1985).

While the BOI-supported restoration is being worn, one must expect the bone volume to increase as a result of functional loads. This may result in the pontic area coming into direct and tight contact with the mucosa and that the quantity and direction of the blood flow is changed by the “permanent pressure spot”. If the BOI load-transmitting region was positioned close to the pontic (something that may happen easily with pontics with e.g. vestibular overhangs), the peri-implant bone may exhibit secondary atrophy. The bone, which had been growing due to the existing functional load, will have its own blood supply and drainage cut off by the pontic region. It is necessary to check the pontic regions on a regular basis and to perform subtractive corrections as needed. See Chapter 9.7 for more details.

Any missing teeth in the lower anterior segment can be easily replaced with implant-supported restorations. The anterior segment of the mandible is very stable, so that implants can always be reliably anchored in this area. The following case report illustrates a case in which teeth 42–32 were replaced with two implants, which were used to support a bridge extending over four teeth. A BOI implant was inserted on the right, a compression screw on the left. The radiograph obtained at the 2-year follow-up revealed distinct differences between the implants regarding their effect on the bone. Consider that the blood supply coming from the inside of the mandible is derived from the mandibular artery. In the presence of a BOI implant, any post-surgical pressure building up inside the mandible can always

be drained. Situations of overpressure that will subsequently damage the spongy and cortical structures are thereby avoided. However, this also means that in some spatial situations the blood supply for the crestal implants may be drained away through the osteotomy slot. In the case illustrated, the screw implant is obviously adequately supplied from the left side. Pressure drainage through the right side, where the BOI implant was placed, is either clinically unimportant, or there is enough blood supply from the left side to cover the losses on the right side.

If both implants were inserted on the same side (e.g. the screw implant at 41 and the BOI implant at 42), the screw would hardly be supplied with sufficient amounts of blood from the contralateral left side. In that case, the position of the BOI implants would be rather deleterious for the screw implant, as the distal blood supply would be drained off through the suppuration slot of the BOI implant without ever reaching 41. This situation may result in undernutrition of site 41. Peri-implantitis (supported by poor oral hygiene) may develop by the sheer fact that blood cannot be sufficiently obtained for the bone for lack of intrabony supply. We have observed cases such as these in our practice. In the maxilla, the blood supply is more diffuse, and corresponding problems have not been observed.

9.6.3

Holistic Considerations on Implant Therapy in Fields of Disturbance

Various hypotheses from the realm of integrative medicine – often fixated on the materials – have cast a dubious light on dental implantology.

This resulted in unjustified low acceptance levels of good bone surgery with subsequent implantation within the holistic medical community, which ranges from natural healers and chiropractors to alternative therapists (including holistically trained academic physicians). It has been known since the 1950s that fields of disturbance within the bone can cause problems at any point within the body. Fields of disturbance were also associated with implants, with naturopathy not currently differentiating between the different types of implants. In this way, crestal zirconia implants are currently under discussion as an alternative to titanium implants, although they have the same structural disadvantages for the bone metabolism.

Dysfunctions and pain typically occur as a result of fields of disturbance located within the jawbone. The high incidence of fields of disturbance in the jaw region is simply the presence of and later damage to teeth – damage including caries, root canal treatments, chronic inflammation, minimum possibilities of

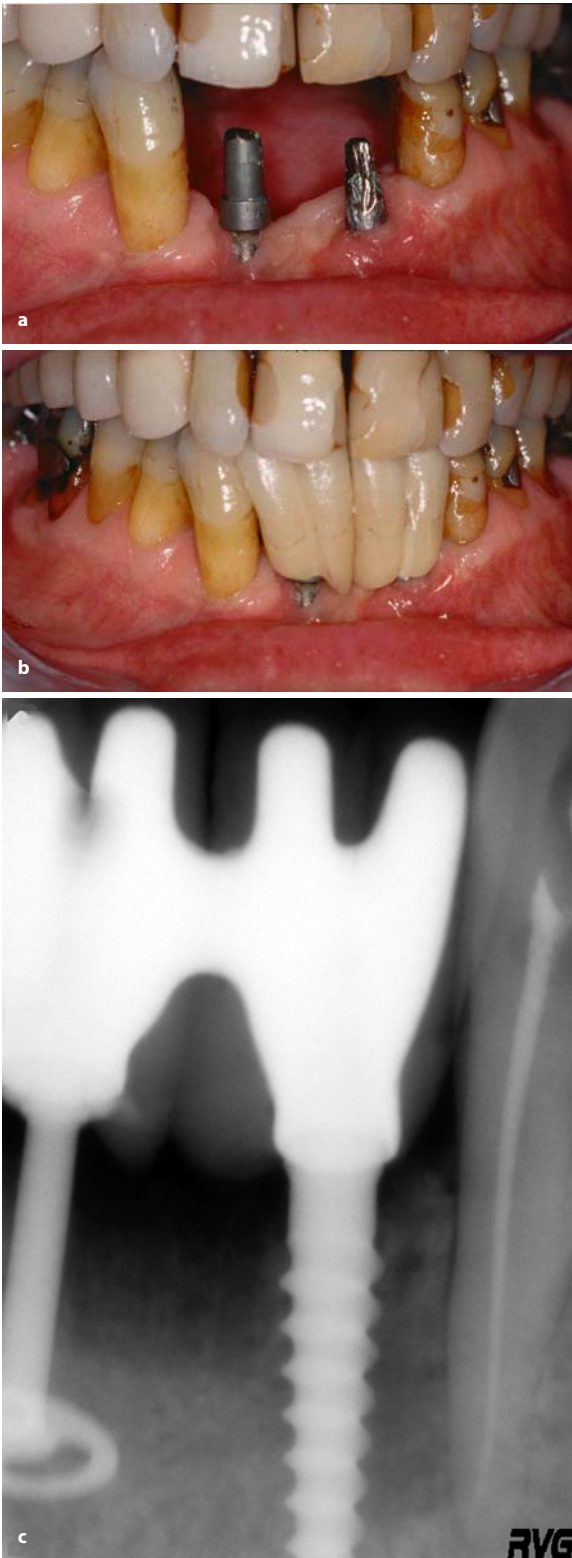


Fig. 9.39a-c. Bridge across 42–32 supported by one BOI implant and one compression screw. The bone located crestally to the disk is mechanically inactive and thus undermineralized. Cortical bone has formed around the enossal portion of the screw implant. The crestal region is mineralized more strongly

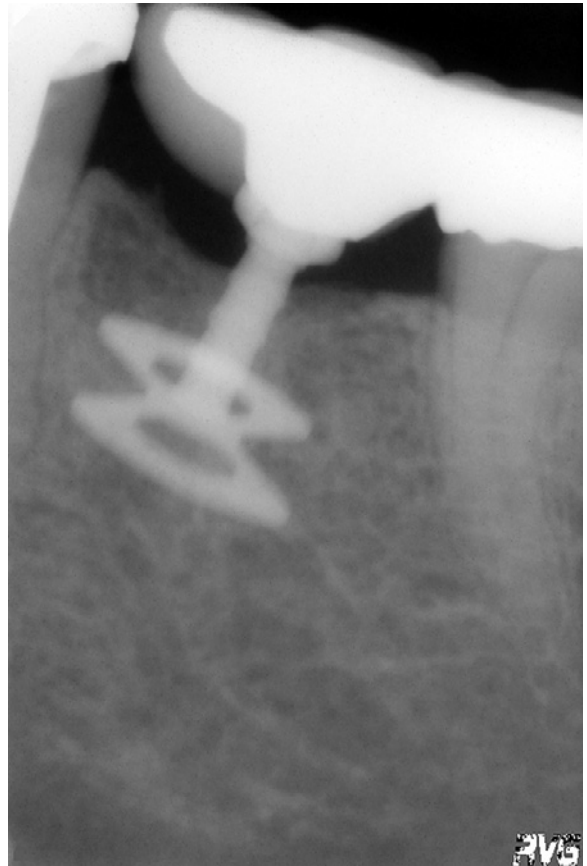


Fig. 9.40. If BOI implants are placed between teeth, similar mineralization patterns emerge. The more strongly mineralized cortical bone of the alveolar socket can be seen around the teeth. Crestally of the disk, the bone is mechanically inactive and therefore rather less strongly mineralized. More pronounced mineralization around the threaded pin is only seen with earlier disk implants (as in this radiograph 5 years postoperatively) that transmit masticatory forces both at the threaded pin and at the disk. This type of BOI implant, due to higher material strength and stronger design, allows less interbony oscillation than implants made from pure titanium

increasing the intraosseous blood supply. No other bone has so many entry gates for disturbances. As shown above, an adverse drainage situation from the bone is where the problem is actually located, not so much the intraosseous blood supply. “Acid” decalcification zones with little metabolic activity are considered a particularly serious burden to the human organism as a whole. These areas are very stable and often exhibit fatty degeneration. Crestal implants in these areas and the postoperative closure of the bony surgical wound with the implant itself further compromise the metabolic situation, preserving or even promoting the character of this area as a field of disturbance.

Relating some peripheral damage to a meridian and associating it with a jaw region where a crestal

implant is located means confusing cause and effect. Often the material (titanium, titanium oxide) will be held responsible for any damage. In fact, however, the problem is hardly with the material; rather, the metabolism of the crestal implant region surrounding the crestal implant is less favourable than before implantation, or at least equally bad. The osteotomy performed for the placement of crestal implants usually does not permit bone regeneration. Logically, then, extensive bone trephination according to Schröder would always have to be performed in connection with crestal implants in order to create the necessary periosteal drainage.

After placement of BOI implants, by contrast, a completely different and much more favourable situation prevails that promotes an improved metabolism of the bone. The osteotomy slots permit uninhibited exchange and drainage, meaning that a balanced metabolism can quickly become established in the peri-implant bone. The lateral movements of the elastic types of BOI implants cause additional mechanical drainage. The osteotomy slot does not close until the flow situation permits. Vertical parts of the implants do not have to be osseointegrated, but can vibrate at very small amplitudes throughout their lifetime. There is a theory that this generates piezoelectric control impulses that stimulate bone growth. From a holistic point of view, regeneration of the bone function will result, via the meridian relationship, in healing impulses throughout the entire body, as described, e.g. by Huneke (1989).

For some years now it has been possible to take computer-assisted measurements of the meridian functions via the resistance of the skin at 24 endpoints on the extremities (see www.medprevent.com for details). We performed comparative preoperative and postoperative measurements in our clinic. We were able to show that, during correct surgical treatment of fields of disturbance and concurrent insertion of BOI implants in those very fields of disturbance, the meridian system is influenced favourably. The following graphs exemplify some of those cases.

With the help of BIO implants it is possible to restore the dentition on a fixed basis in all bone situations. This eases the dentists' decision to extract those teeth which are suspected to impair the metabolic situation and harm the body as a whole. Today patients with this kind of problem are not left as oral cripples for the rest of their life.

9.7

Simultaneous Mineralization and Remodelling Tendencies

F. Krass and S. Ihde

Independently triggered bone transformation stimuli and the distribution of tasks within the cortical bone may act simultaneously and gain importance for bone volume and functional distribution – especially with strategically placed BOI implants/abutments:

The “expansion” of the maxillary sinus continues throughout a lifetime and does not end after the teeth have been extracted. If restorations supported by BOI implants are inserted that have a distal abutment in the more medial region of the maxillary sinus, they will be located in a region that expands caudally in the direction of the restoration, potentially taking the crestal cortical bone with it in a caudal direction. On one hand, this may lead to the pontics contacting the mucosa; on the other hand, it will lead to premature contacts if distal implants were placed in this region. Premature contacts in this area may also be caused by the absence of distal support for the mandible. If natural maxillary second molars are still present distally of the implant-supported bridge, these teeth may become more cranially following the morphological changes of the bone, again resulting in premature contacts on the distal implant borne bridge surface.

Rhythmical functional loads affecting the underlying bone will further increase the mineralization tendency: we are dealing with a self-amplifying control loop. We therefore recommend frequent examination of the extent of mucosal contact and reduction at regular intervals. If this recommendation is not followed, the bone in this region will become ever more strongly mineralized and grow by volume.

This may result in a number of different effects.

- If o-areas in the alveolar region of the maxilla (tooth 4–6) mineralize, this will change the distribution of o-areas and 1-areas over the long term by way of self-trabeculation: Areas beneath the pontic may assume macrotrajectorial tasks (maturing into 1-areas), with other regions in turn losing in structural importance (degrading into o-areas) and potentially being resorbed. It is particularly those areas in the distal maxilla that are located at a distance from the pontics that may lose their statically supportive function and become atrophied (Fig. 9.3). BOI implants integrated in such an area may be destabilized. This may affect areas or implants to the distal or mesial of the newly formed 1-area.

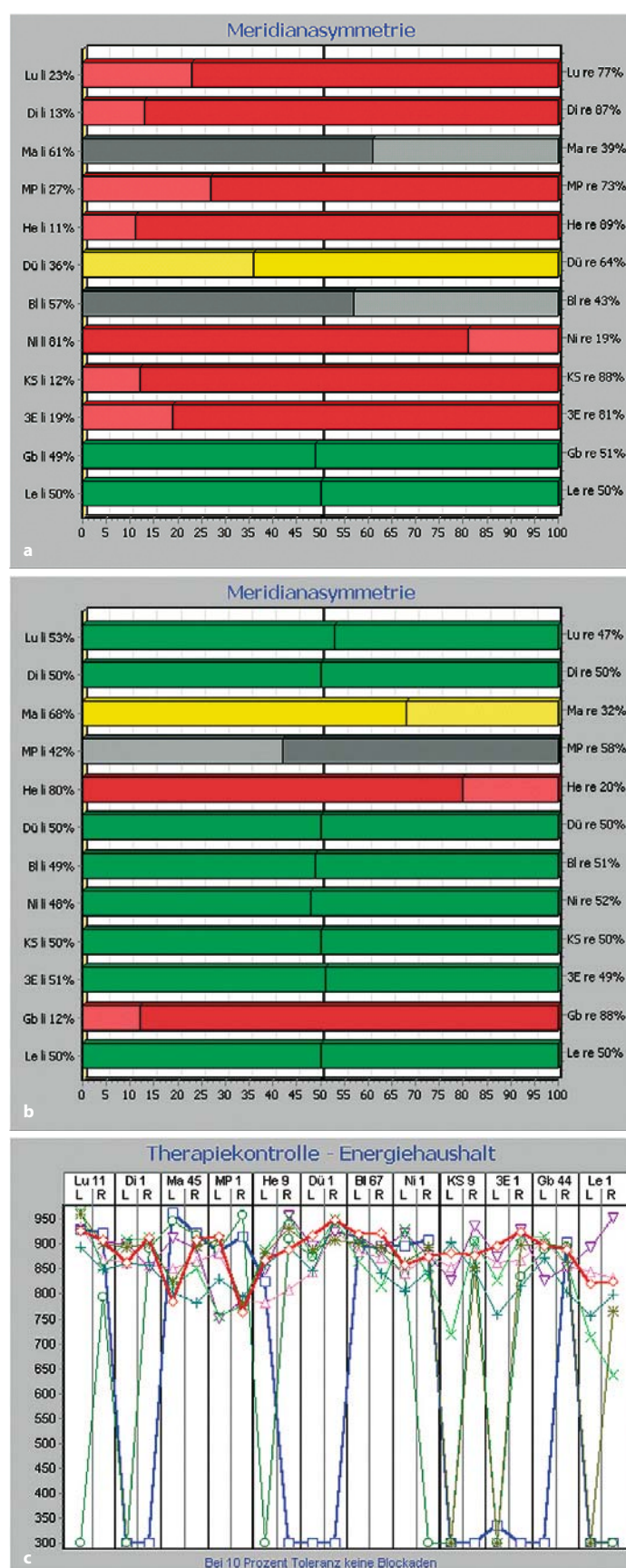


Fig. 9.41a-c. Following a strict dental indication, endodontically treated teeth were removed from the maxilla and mandible of a 66-year-old patient, and a total of eight BOI implants were inserted. The energy balance showed a positive development. **a** Preoperative measurement. **b** Postoperative measurement. **c** Balanced status line (red) after surgery

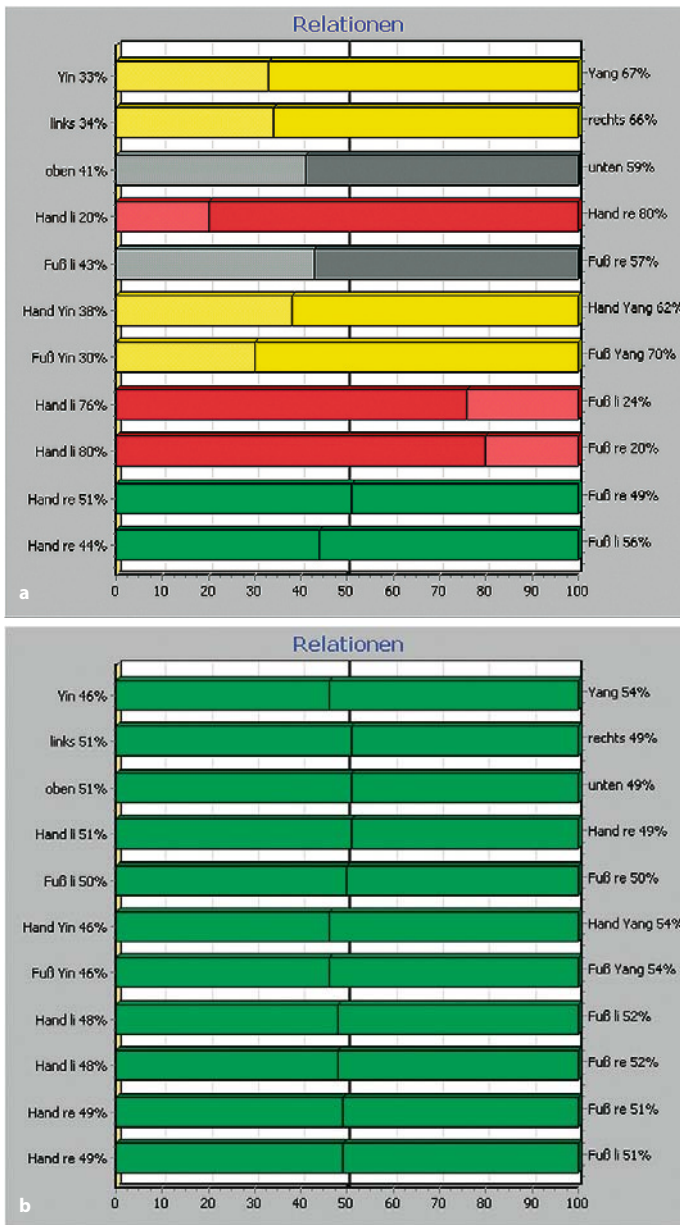


Fig. 9.42a,b. A 54-year-old patient with a bilateral cantilever situation (see Chapter 12) was inserted with three BOI implants, two on the left and one on the right. The measurements were taken with the Prognos Meridian diagnostic system. (www.medprevent.de). **a** Preoperative relations with significant differences in skin resistance at 24 meridian-related measuring points. **b** Relations after treatment of three fields of disturbance by inserting BOI implants

- If, on top of that, an anterior chewing pattern is present, an extruding effect will be exerted on distal implants that may work synergistically with the remodelling process and with the realignment of the maxillary macrotrajectories, cumulatively increasing the risk of implant loss. Adjustments must therefore be performed in a timely manner.
- If the bone below the pontic expands too much, its blood supply and – even more – the flow of blood from the area may be impaired as well. The flow of blood from the area is impaired first, because the pressure in the venous aspect of the capillary system (within the bone) is lower and any blood supply to this region would be contingent on

a reversal in flow direction. Reversing the flow direction implies an increase in bone oxygenation in the cortical region, naturally associated with a reduction in bone volume (Goldhaber 1958). Any mechanical irritation that results in the formation of granulation tissue will have the same effect. Granulation tissue will replace periosteal tissue without assuming the function of the latter. Increased mineralization of the bone tissue is promoted by low oxygen tension (Brighton et al. 1971). An increase in the blood supply owing to a reversal in flow direction (including the area of granulation tissue) will thus tend to result in a decrease in bone volume.

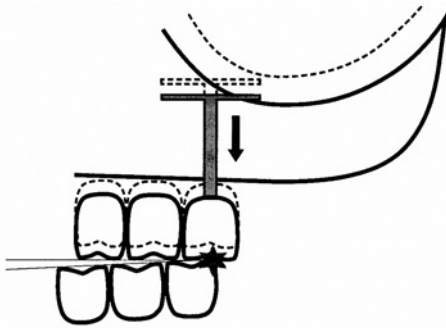


Fig. 9.43. If the most distal BOI implant is placed anterior to the maxillary sinus, the expansion of the sinus can be expected to continue. This will lead to descent of the bridgework and early contacts in the area of the last pontics. This development has to be monitored and frequent adjustments may be necessary (see Videos 25, 27)

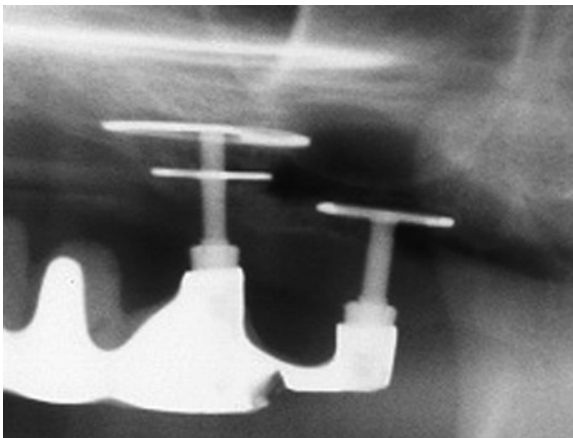


Fig. 9.44. Left distal maxilla. The double-disk BOI implant has monopolized the task of load transmission in this area and is located in a functional 1-area. The bone around the disk of the single-disk BOI implant is undermineralized. This implant is now located in a o-area, even though the implant position would permit maturation to a 1-area. The remineralization trend of the distal implant is very low, which is why at least the threaded pin ought to be removed as soon as any inflammatory reactions (as result of the demineralization of bone) are seen in this area

- Other factors also play a role in determining whether bone tissue is actually lost or created: In the crestal aspect of the distal mandible, the bone formation process may be so strong that vertical bone growth will push bridges off their implant abutments or simply break the BOI implants. A similar development is not seen very

frequently in the distal maxilla. Here, a trend toward vertical bone loss due to macrotrajectorial bone remodelling and stabilization of the basal bone predominates in the alveolar region.

- Overall, the o-1 structure is more variable in the maxilla than in the mandible.
- In case that only one side of the maxilla is equipped with BOI implants, the changes in bone morphology will differ between both sides, creating overload usually on the side with natural teeth.

Pressure on the bone in the area of the pontic can thus result in an increase in bone volume, while rhythmical pressure on the mucosa will result in an increase in the blood supply and therefore in a loss of bone volume. Both processes can occur concurrently. This is one of the reasons why it is a good idea for BOI implantologists to place force-transmitting areas in basal bone regions, away from the restoration. These basal bone regions are more resistant to resorption and protected from the direct effects of pressure from the pontics. If this type of placement is not possible, frequent recalls and corrections are required until stable conditions are reached.

One option for treating unstable implant-prosthetic systems is to add BOI implants and to leave the unstable implants in place. The rationale behind this procedure is that 1-areas can be expected to form in the vicinity of instable implants (the bone near the basal plates representing o-areas), as these areas keep developing due to functional requirements. After the insertion of the additional BOI implant, the 1-area in which it was inserted will lose its load-transmitting functions, which tends to improve the chance of the bone area near the basal plate of the unstable BOI implant maturing and turning into a 1-area again. As a long-term result, both implants will be integrated at a considerable degree of mineralization and will share the task of endosseous-load transmission. This treatment option exists as long as the bone-matrix areas in question are not expected to show alterations as a result of infection. 1-areas are usually expected (or seen on the pantomograph) to reside more deeply within the basal bone areas; the basal plates of the old implant and the new implant should be quite close to each other. If the distance between the basal plates is too large, this treatment approach may not be successful because no interaction between the bone areas may occur.

Functional Considerations as the Guiding Treatment Principle

10.1 Long-Term Function Requires Persistent Balance

While it is easily possible for trees to adapt to the harsh realities of life, for example by growing diagonally, following the prevailing winds, the human body is able to achieve similar feats only at tremendous cost in terms of energy. By contrast with the continuous skeleton of trees, the bony skeleton of the human body consists of separate segments that are spread wide open by and between the muscles.

A slanted posture or asymmetrical function requires an extra amount of energy, since the centre of gravity of the body easily threatens to wander off the human body's relatively small base area. To avoid this and to balance the body, body mass must be relocated, resulting in local overload.

The region of the skull and the neck can be used as counterbalancing mass and moved away from the centre of gravity. However, they can also be the very cause of postural imbalances and of compensatory effects on the extremities or the torso.

Counteracting postural imbalances or dysfunctions in one region or one muscle usually requires



Fig. 10.1. a Freely developing a given potential, unimpeded and unobstructed by external forces, while receiving sufficient, continuous nutrition in well-calculated doses – this is the objective of any life form. What is true of large plants is equally true of the life of any single cell, and of any bone as a whole, and of any individual bone cell. A lack of nutrients and the displacement by competitive growth of indigenous as well as exogenous organisms can cause the bone's chance of survival to deteriorate. To our eyes, this tree appears to be vertical, although the tree trunk is actually not oriented at a 90° angle to the ground. **b** The effects of asymmetrical muscle power are similar – to stay within the same metaphor – to those of a strong earthquake that changes the orientation of objects relative to the ground. External physical factors may cause firmly anchored trees to grow in a slanted direction. The cause of asymmetries in humans is usually located inside the affected organism itself and it may be definitively forgotten. Often long forgotten sufferings remain persistent in single muscles contractions throughout life

excessive activity or exertion on the part of numerous muscles, and this is the reason for the considerable energy deficit.

In actual reality, the small shift between Fig. 10.1a and Fig. 10.1b requires extremely rapid and adequate adaptation, the extent of which is always difficult to perceive: With trees, the balancing mass is hidden underground. In the human body, any asymmetries that exist may be concealed from sight by the soft tissues.

10.2 Introduction

The chewing function can only be fully restored if adjustments are made to obtain a balanced mastication pattern. Traditionally, it has been attempted to achieve this goal by orthodontic, conservative and prosthetic means. Today the spectrum also includes implantological options. We believe that questions relating to masticatory function will define the future of dental implantology and of dentistry at large. Current periodontological, orthodontic and prosthetic concepts need to be thoroughly reviewed and modified based on the realization that any teeth as well as periodontal and bone structures can only be preserved in a lasting manner if all essential functional requirements are satisfied. These requirements will be discussed in the present chapter.

Early intervention is a prime prerequisite for effective functional rehabilitation. All specialists involved in the treatment must respect the overriding importance of the functional treatment objective. The scientific foundations for the treatment rationale described in this chapter are easy to understand (Planas 1992). In this chapter, the reader will learn why the restorative dentist must aim to achieve a stable masticatory function, what he must do to preserve it, and why he should make the necessary adjustments even in situations where the treatment requirements to achieve this goal are extensive.

Patients seeking dental treatments are usually better aware than the dentist what type of problem they actually have. However, since they can neither describe nor demonstrate the problem, they tend to defer to the dentist's judgement. The fact that the thoughts of today's dentists are inordinately centred on technical terms does not help to bridge this communication gap either. People who walk with a limp can communicate their problem better both because they can observe themselves better and because the problem is also visible to others. Unilateral chewing patterns are not usually visible to outsiders, and they cannot be corrected as long as the pathways for bilaterally balanced movements are blocked by muscles and/or hard-tissue structures.

Sometimes one cannot help getting the impression that all basic knowledge that a student naturally possesses on entering a dental school is effectively buried under a flood of knowledge by the time he or she eventually graduates. In a sense, novices have a better intuitive knowledge of how "chewing" works.

In the present chapter, we can only explain the key features of the therapeutic strategy and discuss the basic considerations involved. Practice and experience as well as an uncompromising treatment strategy are the quintessential requirements for successful outcomes. We used to apply the minimal therapeutic solutions taught at the universities and imposed by health insurance providers ourselves for many years. We therefore had ample opportunity to see what disadvantages they involve in the medium and long term. Today we decline any treatment requests that are not aimed at establishing a balanced masticatory function. Surprisingly, the conventional strategy of offering restorative treatment in a piecemeal manner without an overall concept for the masticatory apparatus at large has been used throughout history. Based on this strategy, the patient is left without a balanced masticatory function until he or she has finally reached the point where a complete denture is inserted. This is the first time when a balanced masticatory function is actually established, if only to ensure that the denture is acceptably retained. With the help of BOI implants, we are today able to implement fixed enossal support in a timely, reliable and comprehensive manner. They enable us to intervene in any phase of the gradually progressing collapse of masticatory function without regard to the amount of vertical bone available.

Mastication therapy is the only reliable way to preserve bone by adequate function.

BOI implants offer absolute freedom in the spatial positioning of superstructures, thereby giving us an opportunity to define the position and orientation of masticatory surfaces solely by functional considerations. The treatment objective is to create a laterally oriented masticatory function that is balanced on both sides of the jaw.

10.3 Decompensation of the Masticatory Apparatus

It is always necessary to analyse the aetiology of diseases or dysfunctions before any considerations related to the treatment as such can be made. A wide

variety of parameters – including the size of teeth, the size and position as well as the foundations and suspensions of the basal jaw segments, the occlusal plane, the quality and length of the chewing muscles, body posture and mimic muscles – are intertwined in a biophysical continuum that remains to be investigated in detail. These parameters come in countless configurations. In this way, the functional spectrum of human development has to be extremely broad to allow “serial production” of functional individuals even under the most adverse of conditions and the most inappropriate of configurations. In engineering terms, one could say that the production-related and structural tolerance limits are used to the fullest extent possible. These processes are driven by growth and function. Once the endpoint of growth has been reached, the only force that continues to influence morphology in constructive manner is the force of function. In addition, degenerative and hormonal influences are gradually coming to the fore as well.

Once the endpoint of growth has been reached, functionally viable results will be present even though the departure points may have been extremely different or unfavourable. However, not all of these results are stable. Some of them are “just about” balanced rather than “well” balanced. The chances that these results can remain stable for a lifetime are slim. The phase of growth is followed by a phase of decompensation that will last for the rest of the patient’s life and is triggered by asymmetrical function – that is to say, by the fact that elements of the skeletal system are utilized in a non-balanced manner.

The main factors responsible for the progressive decompensation of the masticatory system are illustrated in the following subsections. The important part for the daily requirements of diagnosis and treatment in the dental office is to identify the temporal sequence and relative importance of these various factors in each patient’s gradual decompensation of the masticatory function. We are talking about the impact of joints, muscles and masticatory surfaces, but we are also talking about the “sloth factor” as a basic principle of all human existence. With regard to our topic at hand, this means that an individual will always prefer the “easier” chewing side, even though a voluntary effort to use the side where chewing is harder would actually be the gentlest treatment imaginable.

10.3.1

Avoidance Patterns

Reflexive avoidance of pain has the greatest effect on function and, by implication, on form. According to Kawamura (1974), masticatory movements are

regulated by the following factors:

1. Muscle-related factors
 - A. Muscle spindle mechanisms in muscles attached to the mandible
 - B. Stimuli coming from Golgi’s corpuscles in the muscles attached to the mandible
 - C. Afferent stimuli coming from the neck muscles
 - D. Pain in the muscles attached to the mandible
2. TMJ-related factors
 - A. Stimuli coming from mechanoreceptors in the articular capsule
 - B. Afferent stimuli coming from accessory ligaments
 - C. Pain originating from joint structures
3. Oral, facial and perioral soft-tissue sensations (pain, stiffness, mechanical sensations and thermal stimuli)
4. Tooth-related factors
 - A. Toothaches and periodontal pain
 - B. Stimuli coming from the periodontal ligament
5. Pharynx-related factors: Pain, hypomobility, injuries, thermal stimuli

Premature contacts associated with tilted and/or elongated teeth may gradually give rise to deviations that change the position of the mandible relative to the teeth in the maxilla, causing the chewing activity as well as the activity of chewing muscles to shift towards other jaw regions without causing acute pain.

Most denture-related pressure sores, but also periodontally induced tooth mobility and destruction, will massively regulate the masticatory force downward, something that is ultimately also tantamount to pain avoidance.

10.3.2

Unilateral Chewing and Side Switching

Any edentulous spaces, tilted teeth and/or premature contacts will reduce the efficiency of chewing, a greater effort is required to achieve the same chewing results on the affected side as on the intact side. The brain will quickly register this imbalance and switch the chewing load to the intact side. The teeth of the support zone on the working side are rather prone to intrusion, whereas the contralateral teeth are more likely to hypererupt over time due to the smaller intrusive effect of the chewing muscles on the non-working side. At the same time, the teeth on the working side of the maxilla will migrate somewhat in a centrifugal direction, while the contralateral teeth are more likely to undergo medialization. This process is clinically and radiographically evident as a midline shift towards the working side. As the functional masticatory angle

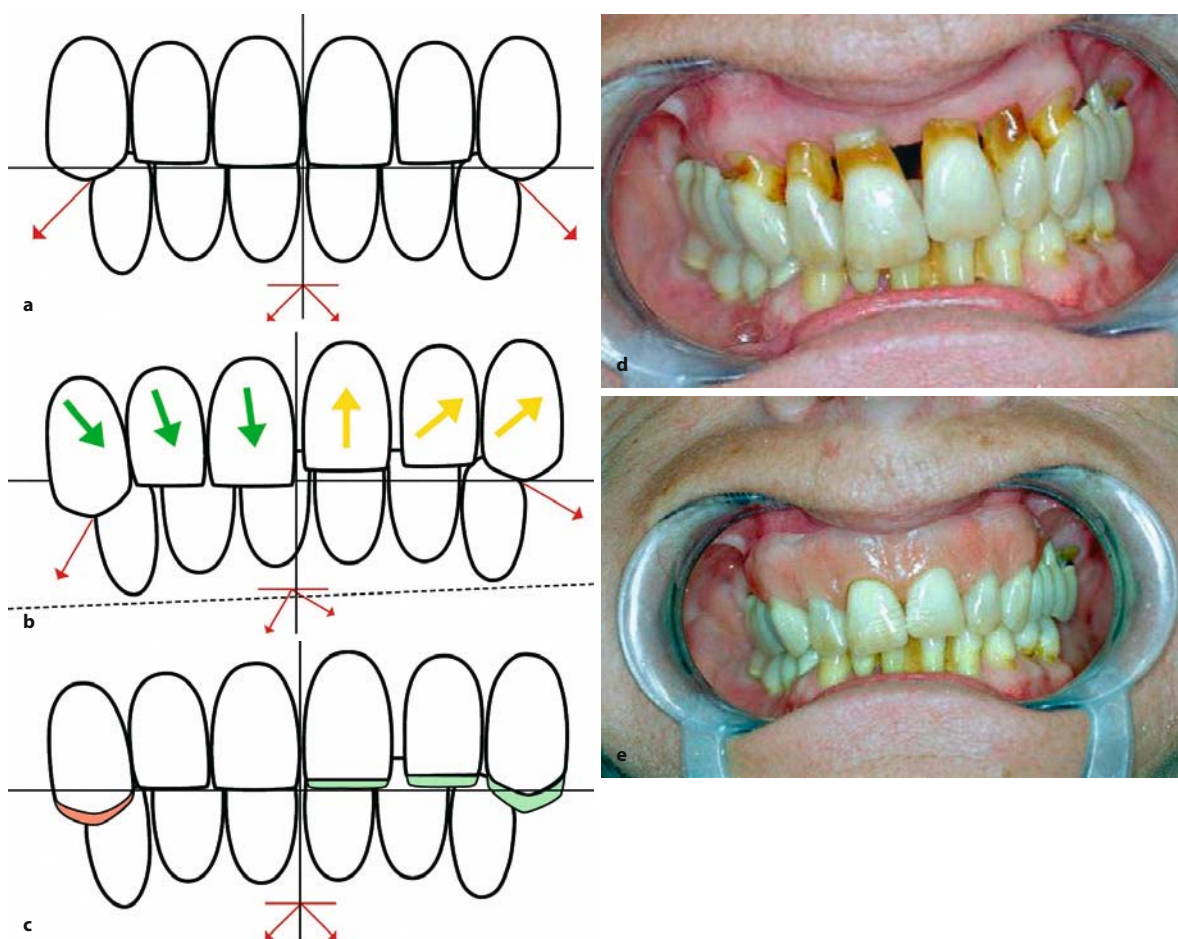


Fig. 10.2. **a** Baseline situation with aligned midlines and symmetrical AFMP angles. For maintaining equal mastication on both sides of the jaw, it is not really important to have smaller or larger AFMP angles. It is only important that the angle shows the same value on both sides. **b** In the event that one side develops out to become the preferred chewing side (here *right side of picture*), the midline shifts to the working side. Teeth on this side are intruded and flared lateral, while the dentition on the non-chewing-side are elongating and move medially (*green arrows*). The occlusal plane descends, and the AFMP angle increases on the non-working side. **c** In order to correct this, material must be added to the crowns on the working side. At the same time grinding of medialized cusps on the non-working side is performed. This way the bite is being lifted “unilaterally” on the working side. **d** Typical clinical situation after a unilateral chewing pattern has been present for many years. Teeth 21 and 22 were intruded by the masticatory force while teeth 11 and 12 became elongated. **e** In the absence of gingival recession, or if the dental necks are covered by an epithesis (as in this figure), the true relationships are actually not too obvious. Dentists are used to an overly narrow field of vision. Deviations of the masticatory plane are more obvious when viewed from a distance

of Planas (AFMP, angles fonctionnels masticatoires de Planas) on the non-working side changes as a result of mesialized and elongated teeth, the chewing pattern becomes unilateral for good. The greater the bilateral discrepancy in terms of AFMP angles, the more pronounced the unilateral pattern. The patient will increasingly have trouble chewing on the non-working side as the extent of mouth opening required on that side to do so will increase steadily. Interestingly, the chewing side is not defined by the absolute value of the AFMP angle but by the relative difference between both angles. Patients with deep-bite relations may thus reveal a large AFMP angle because their occlusal relations do not permit any

flat lateral chewing movements in the first place.

Developments such as these can be readily verified in the OPG if they only are present long enough. Not only does the midline shift become evident, but the condyles obtain different shapes due to the loading imbalance. The condyles on the working side will be large and rounded, while those on the non-working side will be flattened towards the anterior. More importantly, the long distance they have to cover as they advance forward will make them smaller on the whole. The articular eminence will become flatter as well.

If the alternative chewing side is missing already and the chewing ability on the preferred side is

lost into the bargain, the patient will quickly seek implant treatment. In this situation, many patients report that the loss of one specific tooth has left their chewing ability seriously impaired. Their dentists, on the other hand, will often find it hard to understand or downright illogical why one specific tooth should have had such far-reaching consequences when multiple teeth are missing. The dentist should consider himself warned by such statements. After all, any kind of dental treatment should always aim to establish a complete set of masticatory surfaces that interact equally well throughout. The patient should be advised to have the restorative treatment performed comprehensively rather than unilaterally. This is the only way to treat the unilateral pattern with a relatively good chance of success, thereby greatly enhancing both the longevity of the implants and the outcome of the restorative treatment at large. In crestal implantology, a terminal implant in the first premolar position is sometimes added due to the heavy dependence of these designs on the vertical thickness of the available bone structure. Some authors even recommend placing any implant-supported crowns slightly below the level of occlusion. While we shall ignore for the purpose of this discussion whether treatments of this type make any sense at all, they are clearly unnecessary and indeed counterproductive with BOI implants. After all, it is virtually always possible to place these designs in the tuberosity area to obtain technical abutments in these positions, so that a functional occlusal table can be established that extends right to the position of the first molar. In this way, it is always possible to establish a uniform mastication pattern characterized by masticatory surfaces of equal length and width on both sides of the jaw. The development of a preferred chewing side cannot be avoided if the APFM is too different over a period of time. On the other hand, absence of distal balance on one side will also trigger the development of a preferred chewing side even in cases with symmetrical AFMP angles. We learn from this that gaps in the arches are often less determining for the deterioration of the chewing pattern than differences in AFMP angles (with subsequent vertical differences between the sides) and differences in the situation of distal balance. In fact a preferred chewing side will intrude the teeth in both arches of this side and lead to elongation on the opposite site. This alone prevents balance when the individual tries to use the non-chewing side during mastication.

10.3.3

Restricted Movement

Problems related to mastication may be caused by restricted movements. Muscle parts unused over

longer periods yield the same effect as dissected or paralysed muscles. Malpositioned teeth will block regular movements and give rise to cramps or atrophy of muscles. Having been present for a long time, these problems will persist even after the cause has been removed (e.g. after tooth loss). Restricted chewing movements may occur at any time and have to be treated without delay.

The diagnosis is simple:

- On being asked to perform chewing movements with the oral cavity empty, the patient will reveal one of the following movement patterns:
 - Pure chopping movements
 - Advancing movements (anterior chewing pattern)
 - Unilateral lateral movements
 - Bilaterally balanced grinding movements

Pure chopping movements and advancing movements are mainly observed in situations of deep bite/vertical overbite (i.e. in cases of primary TMJ dysfunction). Unilateral lateral movements are observed in the presence of discrepant AFMP angles. Bilaterally balanced grinding movements are only observed when the AFMP angles are about equal.

Precautions must be taken to prevent restricted chewing movements in the treatment phase.

- When the dentist inserts the prosthetic superstructure, he or she must look beyond occlusal parameters but ensure that a uniform mastication pattern is within reach for the patient. Due to peripherally or centrally induced persistent muscle dysfunctions, patient with pre-existing functional disorders are rarely able to perform bilateral grinding movements right away after, even if “all” interferences have been eliminated and the AFMP angles optimally adjusted. These patients need to undergo periodic treatment sessions to relax their muscles and practise appropriate chewing movements under physiotherapy guidance. We found that a period of 3–4 weeks between adjustment sessions is better than applying changes at shorter intervals. The muscles need this time to establish a new (pre-)final balance, arrange for sufficient blood supply and drainage and build up forces.

Physiotherapists like to perform their treatments at short intervals (either daily or every other day), presumably to optimize their schedules. We do not think that these short intervals are appropriate when the objective is to stabilize the masticatory pattern. In our experience, it is better to perform physiotherapeutic sessions once a week, with chairside subtractive/additive adjustments after every three to four sessions. The muscles associated with seriously dysfunctional dentitions simply need more time to adapt and

to recover a desirable level of masticatory forces. Physiotherapeutic sessions performed at shorter intervals raise the overall costs without achieving their objectives more effectively or even faster.

- More information on position-related problems can be obtained by observing the closing movement of the jaws. If this movement proceeds smoothly without involving midline deviation, then the midline is presumably correct. A twitching movement, by contrast, indicates that the habitual occlusion is at variance with the retral and horizontal TMJ positions. These muscle twitches indicate the presence of an abnormal intercuspitation pattern. While anatomical landmarks are also informative, they are not altogether reliable, considering that all cranial structures are mobile relative to the centre of the skull. Both the labial frenulum and the line of the median raphe may change relative to the centric position of the mandible.
- If the bone volume in the maxilla is small and asymmetrical, or if the configuration of BOI implants is asymmetrical, then the implant-restoration will not be uniformly stable against the cranially oriented chewing pressure. The same is true if the chewing forces are not balanced on both sides of the jaw at the start of treatment. From a clinical viewpoint, the resultant implant-restoration systems will be asymmetrically intruded once they are osseointegrated. This may quickly give rise to a slanted masticatory plane and discrepant AFMP angles with all the functional consequences described for this type of situation.
- Once the teeth have erupted, their arrangement will be defined by occlusal and masticatory parameters during normal physiological development. In this process, the bony macrotrajectories are reconfigured in such a way that tooth position remains relatively stable. In the presence of excessive muscle forces, the teeth participating in mastication may change their position such that the bony macrotrajectories take over from the occlusal structure as the main determinant. In these situations, individual teeth will change their position and acquire non-physiological contact positions or lose contact with their antagonists. This process may occur at any age. In many cases, the enhanced muscle tone is due to psychological tensions. Hypertonia of the internal chewing muscles cannot be visually detected. The reader is referred to Chapter 17 for a detailed discussion of craniomandibular syndromes in patients with psychological disorders (Chapter 17).

10.3.4 Non-physiological Hypomobility Due to Lack of Abrasion

Abrasion of deciduous teeth is not only “normal” but is a prerequisite for normal correct development. On the one hand, the foods available today may not be abrasive enough or may not stimulate the chewing activity sufficiently to create abrasion. On the other hand, today's children may lack the physical activity and general training required to build up the necessary muscle strength in the first place. In spite of that, people grow taller than in former times as a result of continuous food supply and favourable hormonal conditions, which multiplies the potential damage inflicted by lever forces in the event of malfunction.

Asymmetrical abrasion of deciduous teeth is suggestive of unilateral function. This situation can be easily remedied by occlusal adjustment therapy, which is normally started on the canines. Additional steps will be required if the adjustment therapy fails to establish a harmonized masticatory function characterized by a sufficiently lateral movement pattern. In this way, the purpose of mastication therapy is to liberate the movement potential that is basically present but is obstructed by hard-tissue structures. Painful changes from deciduous to permanent teeth are a particularly common cause of persistent dysfunctions and restricted movements. These problems develop faster than in adults as the processes of bone remodelling are particularly extensive in this phase. Occlusal adjustments will help to initiate spontaneous healing.

If morphological discrepancies are present as a result of delayed therapy, treatment with orthodontic devices becomes necessary. Treatment must be expanded if the bone width is inadequate when the first molars erupt. Unilateral chewing patterns in the early transitional phase from deciduous to permanent teeth will quickly give rise to incorrect tooth positions that will no longer resolve spontaneously. For instance, a unilateral chewing pattern associated with minor elongation of the first molar and slight anterior migration will quickly create unilateral Class II relations that will persist forever if left untreated.

In our experience, the deciduous canines pose the greatest obstacle to laterotrusion in the deciduous dentition. Children of all ages will instantly switch from chopping movements to a laterally oriented chewing pattern once the cusps of these canines are reduced. The dentist may want to try this approach and, once convinced of its usefulness, include it as a routine prophylactic measure into his or her therapeutic spectrum. Children tend to welcome the outcome of this measure much more spontaneously

Table 10.1. Typical age-specific distributions of abrasion, AFMP angles and tooth contacts. If non-abraded cusps are present for too long, the AFMP angle will remain too great. Today's foods are too soft to induce adequate abrasion. Bruxism does not normally abrade the teeth in a bilaterally balanced manner (Planas 1992)

Age (years)	Abrasion	AFMP	Diastema
2	–	+++	–
6	+++	0 degrees	+++
13	–	+++++	–
20	+	++++	–
40	++	+++	–
60	+++	+	+
80	++++	0 degrees	++

than adults, although the effect is basically the same in both age groups. Apparently, some adults have a hard time accepting unimpaired movements because the restricted muscle function is ingrained much more deeply than in children's minds.

10.4 Clinical Diagnostics

Visual analysis of the grinding movement will provide a quick overview of the required scope of diagnosis. Complex electronic measurements will only capture the current status of muscle-induced problems, thereby offering no relevant information for the type of therapy that will be discussed below. Rather, the mouth should be slowly opened and closed by the patient. If these movements do not involve any deviations, the masticatory function is presumably normal.

As we have mentioned before, anatomical landmarks such as the median raphe line or the labial fraenum may be informative, but they may also be deceptive. Orthodontic pre-treatment or unilateral extractions will leave the jaw permanently deformed, which is also true in situations of prolonged unilateral edentulism (also see Chapter 22, Case Study #1).

The presence of any dysfunctions can be ruled out with great certainty if the excursive movements of the mandible are largely identical towards both sides, also involving equal AFMP angles. All anterior chewing patterns are pathological in nature. The same is true of any chopping patterns with few

lateral components, which are intermediate in severity between physiologic grinding movement and anterior chewing patterns.

Pathological processes are also indicated by distally elongated teeth in the posterior segment of the mandible and slanted masticatory planes involving unilateral elevation of one mandibular canine.

In the vast majority of cases, painful symptoms are initially only present on the working side. They are usually caused by spasmodic contraction and hypoxia of the lateral pterygoid muscle, which is underperfused because it can no longer be extended. In advanced cases, the symptoms may spread to the neck muscles, mainly affecting the working side once again.

There is a direct relationship between cusp inclinations and chewing ability. Unilateral chewing patterns are associated with unilateral abrasion, intrusion of the posterior teeth on the working side, and elongation of the posterior teeth on the non-working side. In the presence of anterior chewing patterns, the anterior teeth become elongated in the maxilla and in the mandible. Both jaws do not show the same pattern of extrusion and intrusion. The mandible is made up of two distinct functional blocks of equal size that are separated by the median plane. The maxilla, by contrast, is subdivided into three functional blocks – i.e. one anterior block and two posterior blocks. In other words, any masticatory activity will always involve one of these blocks in its entirety. Therefore, situations may arise in the maxilla where the anterior teeth on the working side are intruded while those on the non-working side become elongated. Since the anterior chewing pattern will stimulate movements of all teeth along the same functional block, all teeth along the block would normally become elongated, which is prevented in a unilateral manner by the local intrusive forces present on the chewing side.

If the effects of elongation and intrusion fail to cancel each other over an extended period of time, the masticatory plane becomes slanted. The maxillary premolars on the working side are the first teeth to be intruded. At the same time, the antagonistic premolars and the adjoining canines in the mandible become elongated. Once the point of no return is reached, the masticatory plane will remain permanently slanted, and the individual is unable to regain equilibrium without professional help. The masticatory function becomes unilateral rather quickly. As a result, the teeth on the working side are lateralized and the dental arch is enlarged. The maxillary teeth on the non-working side, by contrast, are medialized and become elongated. Early manifestations typically include crowding and rotation around the lateral incisors. Very often, the

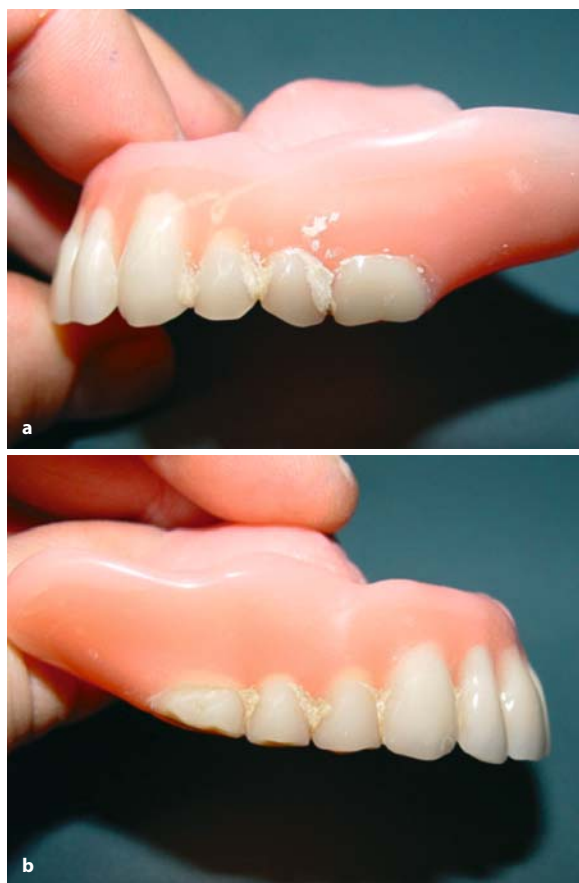


Fig. 10.3a,b. Both posterior segments of a complete denture. A curve of Spee is visible on one side and reversed on the other side

curve of Spee becomes reversed on one side and enhanced on the other side of the jaw.

10.5 X-Ray Diagnostics

The panoramic radiograph offers important information both on the current intraoral situation and on any past events in terms of side switching, migration of the mandible and midline problems.

Side switching may happen once again after any teeth on the working side have been lost or the non-working side has been restored, which will sooner or later be reflected in the shape of the condyles. Anteriorly flattened condyles on both sides of the jaw indicate that the chewing side has changed several times in the patient's history.

The term “hinge axis” as used at dental schools is a misnomer that misses the point completely. The TMJ is guided and kept in place by muscles exclusively. Osseous border structures scarcely participate in “condylar guidance” at all. In addition, the

morphological adaptability of the TMJ is extremely good. The articular eminence often interferes with the extension of the lateral pterygoid muscle.

10.6 Relaxing Joints and Muscles

Anterior jigs are a very safe and useful tool for diagnostic and therapeutic purposes. They allow the TMJs to relax to some extent. Having said that, the chewing muscles are frequently unable to relax in a matter of hours after having been greatly hypertonic for many years, but this process may take several weeks or indeed months. The intraoral treatment is quickly completed. The anterior jig will effectively restore a more central position. Subsequently, a distal build-up with silicone or acrylic resin can be performed to adjust the biomechanical centre and bring the muscles into focus. This approach will normally restore a straight path of mouth opening. On the downside, this “quick fix” will hardly allow the masticatory plane to be corrected at the same time.

Maxillary premolars and molars that are rotated and/or elongated may also constitute unilateral obstacles to function and have to be occlusally supported or extracted when in doubt (Fig. 10.7).

10.7 Periodontal Consequences of Function

Current research in periodontology tends to focus on two areas:

- Formation of new bone at sites where the native bone structures could not be maintained.
- Eliminating bacteria, which are held to be the sole cause of periodontal disease and bone loss.

Less attention is devoted to jaw function at large and to the periodontal consequences of function. In our view, the causal relationships in this connection are routinely confused. The dysfunctions should be regarded as the primary causal factor and any bacterial problems as a follow-up effect. While diagnostic and therapeutic approaches that are solely focused on the bacterial load may succeed in controlling acute periodontal problems, they are unable to stop disease progression or restore any missing bone structures in a lasting manner. A truly sustainable outcome can only be achieved once the functional requirements are met.

In our experience, it is occasionally sufficient to rehabilitate the jaw that is more severely affected by tooth loss and periodontal disease because the opposing jaw will then take care of itself. This

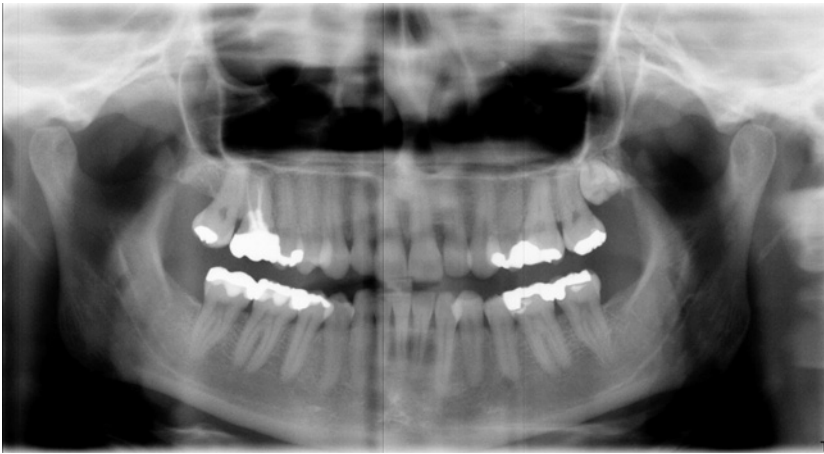


Fig. 10.4. The condyles in this mandible of a 40-year-old woman are about the same size and similarly rounded on both sides of the jaw. Side switching has not occurred even though the upper left wisdom tooth is still impacted. Surprisingly, unilateral extraction of an upper premolar has affected neither the masticatory function nor the morphology of the TMJ in this situation



Fig. 10.5. This 40-year-old woman reveals distinct signs of unilateral chewing. The condyle on the right is substantially larger than the condyle on the left, indicating that unilateral chewing on the right side must have been present over many years. Since both condyles are anteriorly flexed, they must have moved retrally in another phase

presupposes that the occlusal situation between the two jaws is intact and allows a sufficient degree of load transmission to the periodontal structures. It is therefore recommended to close any missing spaces, even if only in a temporary manner. This approach may sometimes avoid further extractions in the opposing jaw. Periodontal rehabilitation, ideal occlusal loading, good oral hygiene and an appropriate chewing force will support the inherent powers of spontaneous healing.

10.7.1

Muscle Power and Chewing Pattern

Both the presence of strong stimuli from the periodontium and the development of preferred chewing sides as such have an impact on the level and quality of muscle activity. In this way, the muscle power (mainly of the masseter and temporalis muscles) will decrease as periodontal destruction progresses in the presence of an intact support zone. This is the only way tooth loss is avoided for years

even though the affected teeth may be greatly mobile. Lowering the amount of the masticatory forces will result in a lack of drainage through the periodontal tissues. Those tissues will then be widened to enable sufficient outflow. This widening is combined with an increase in mobility.

The important role of chewing power regulation is especially apparent in patients with skeletal Class II relations. In full-blown cases of this pathology, anterior contacts are missing. The masticatory force will be reduced to avoid pain only when the teeth cut into the palatal mucosa. The chewing power will increase because the highly regulating effect of the oblique surface contacts on the anterior teeth is missing, which will give rise to further intrusion of the posterior teeth while the anterior teeth become simultaneously elongated. This will aggravate the deep bite even further. Furthermore, patients with a deep bite have to open their mouths wider to introduce the same amount of food than patients with normal relations. The mandible is thus flexed further, the degree of mineralization

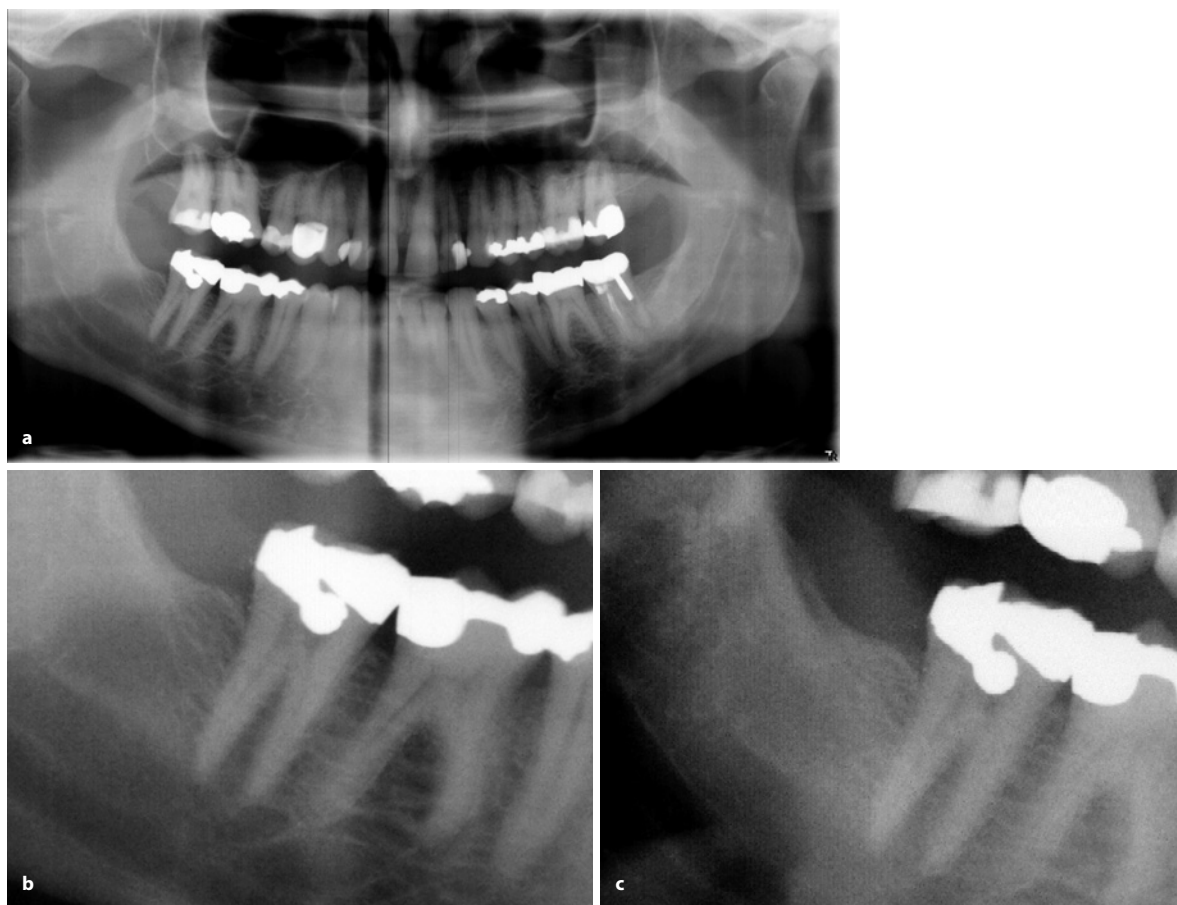


Fig. 10.6a–c. The working side is not only evident from the condyle but also from the cancellous bone structures in the horizontal branch of the mandible. **b** Relatively horizontal lines in the area of the second molar. **a** By contrast, a massive crestal bone structure at 37 without any horizontal lines. **c** The same case 6 months after the functional obstacle has been removed. The horizontal lines distally to 47 are now greatly reduced, and the crestal jaw area is more heavily mineralized than at the start of the therapy. **a** This condylar structure is typically associated with unilateral chewing on the left side. The right condyle (non-working side) is flattened. The chewing problem was due to the overly long vestibular cusp at 14, which prevented laterotrusion towards the right side. Therefore, the masticatory function moved to the left side. The implicated cusp may not have been excessively long from the outset. The same functional outcome would result from lack of palatal support of the crown or from medial migration of the lower premolar, to name only two examples

in the area of flexion is functionally reduced, and proximal contacts of the posterior teeth during mouth opening are reduced. The reduced proximal contacts will promote periodontal destruction, thereby accelerating further intrusion even if the muscle power may remain constant (Jernberg et al. 1983; Gould and Picton 1966). The development thus perpetuates itself because the distal chewing areas are utilized less than the anterior areas. Reinforced bony structures have to be built in the area of the jaw angle. We have observed that the white lines visible at the anterior angle of the mandible on the panoramic X-rays (linea obliqua) become more pronounced and caudalized. This is a logical reaction of the bone to the masticatory forces acting through the long lever created by anterior chewing patterns. Molar chewing patterns may exhibit the same forces, but the

leverage situation is more advantageous compared to an anterior chewing pattern. The enossal blood supply crestally to the heavily mineralized area (in the posterior segment) is thereby compromised, thus restricting the periodontal defence potential. This will sooner or later promote periodontal disease on all tooth surfaces to the crestal of the white line. The white line can “catch” – depending on the spatial situation – large parts of the roots of the mandibular second molars, but hardly ever the roots of the first molars or the second premolars. Second molars in these cases this have a good chance of survival (even if they carry wide-span bridges), while first molars do not. They tend to get lost early and resist all attempts at periodontal treatment. The development of the white line and the question as to which part of the root is “caught” by it will decide the fate of

the tooth as well as the fate of the BOI implant. BOI implants must therefore be placed below the white line or at the place where it runs out, or in the area where one would expect the line to be or develop with higher masticatory forces present. The white line is created by highly mineralized vestibular bone showing very little remodelling. Any BOI implant placed there will usually automatically touch, on the lingual aspect of the mandible, the region where the mylohyoid muscle is attached; this area, too, is quite resistant to resorption.

Patients wearing tooth-supported fixed bridges develop higher masticatory forces than patients with natural teeth (Kraft 1962). Presumably, the periodontal receptors provide inaccurate and reduced feedback in these patients.

The closing movement of the jaw is not only a function of relative muscle power but also of the sequence of muscle activity. The investigator can evaluate the muscle tone compared to his own muscle activity and demonstrate the difference to the patient. The muscles on the side where the premature contacts are present will contract first, while the reaction of the contralateral muscles is slightly delayed but then takes longer to resolve.

10.8 Occlusion Versus Mastication

The dental literature is rife with proposals for occlusal and masticatory treatment concepts. Some approaches and some advices are compatible with others, while others are mutually exclusive.

We shall first discuss what happens when Nature takes its course without intervention by dentists. Scaife and Holt (1969) investigated the distribution of occlusal and functional patterns in a total of 1200 adult patients. Of these patients, 940 (78.3%) presented with Angle Class I, 230 (19%) with Angle Class II, and 30 (2.5%) with Angle Class III relations. Canine guidance was bilaterally intact in 640 patients (57%) and unilaterally intact in 184 patients (16.3%). Pure protrusion was associated with no canine guidance in 99.4% of patients. The canines of 91% of patients exhibited centric contacts. It is necessary to keep in mind that these figures may vary widely depending on the population investigated because Class III relations are known to involve high endemic prevalences.

Broken down by Angle classes, canine guidance was present bilaterally in 57% and unilaterally in 16% of Angle Class I patients. While these percentages were even higher among the Class II patients (67% bilateral, 17% unilateral), they were considerably lower among the Class III patients (13% bilateral, 20% unilateral). Age groups were not discussed in

that study.

Unilateral or bilateral canine guidance is present in 70% of patients at age 25 but only in 40% at age 45. This difference results from abrasion of the canines and elongation of the premolars and molars. The older the patient group observed, the higher the prevalence of group function and abrasion.

Numerous reconstructive concepts do not take this into account. It is still common practice at dental schools to wax up three-point contacts, and trainees of dental technology are still taught to work towards pronounced youthful cusps. The Polz's cusps introduced in the 1980s were based on the realization that this type of occlusion is unsuitable for older patients. These designs made it possible to combine freedom in centric with cusps that were aesthetic from the dentist's perspective. Polz's cusps are not really cusps. In effect, they are rather level occlusal surfaces with an aesthetically designed surface pattern. From a functional viewpoint, these surfaces constitute an abraded dentition, allowing the dental technician or the dentist to achieve canine guidance or group function as needed. In daily dental practice, the objective of achieving a trigger-free masticatory function can be achieved more easily and safely by designing occlusal stops (Beyron 1969).

In the final analysis, both concepts may work perfectly well because it is really up to the patient to decide how the occlusion is to be utilized and whether it will be used or abused. Both types of occlusion are compatible with good oral health, and both may involve problems if the patient, whether consciously or unconsciously, opts for dysfunction (McAdam Blake 1976). Whatever the case may be, the interlocking of cusps has to be reduced or eliminated over the course of life. This cannot usually be achieved with abrasive instruments because the



Fig. 10.7. This rotated and elongated second molar in the maxilla does not allow physiological laterotrusion and prevents the bone structure around the vestibular roots of the molars from being functionally utilized. The resultant local disuse atrophy usually gets diagnosed as “idiopathic periodontitis”, which does not reflect the true cause. The vestibular cusps of the molars are not subjected to any kind of function in this situation

deepening bite will invite anterior chewing patterns.

Anyway, occlusal contacts are hardly ever established during chewing. Orderly rhythmical movements, which will be discussed in detail below, are much more important for mastication than orderly occlusal relations. Evaluating a prosthetic reconstruction based on occlusion is like testing boots by just standing in them. Boots that are “made for walking” can only be obtained by including the parameters of mastication as well.

Mastication concepts are mainly realized in the form of removable complete dentures, but they do play a vital role in BOI-supported restorations. Prosthetic restorations that are based on these concepts are always preferable. They usually require extensive restorations in the opposing jaw as well, even though the patient may see no need for this.

10.9 Neuromuscular Control in Implant Patients

In patients with natural dentitions, the periodontal nerve endings have much less of a control function than the spindles and tendons of the chewing muscles. The TMJ is, of course, a complex proprioceptive organ as well. These joints appear to have a much greater freedom of physiological movement than, for instance, the joints of the arms and legs. In addition, the lifelong morphological adaptability of these fibrous joints is unique among the hyaline joints of the human body. The potential of bony appositions decreases with the widening of the TMJ joint space (especially in patients with anterior chewing patterns) because lower direct or indirect transmission of forces to this area of the bone occurs while the joints position becomes more variable (Hielscher 1961).

The situation concerning neuronal control is somewhat different in the presence of implant-supported restorations because there is no feedback from the periodontium, which would normally participate in the control mechanism. A similar type of reflex can be induced via periosteal pain in situations where the disks of BOI implants project laterally from the cortical bone margin. In the presence of excessive functional or parafunctional loads on BOI implants, the bone around load-transmitting disks will first react by developing reversible undermineralized zones. Once the disk becomes slightly mobile, periosteal pain will develop that may per se regulate the masticatory forces

downward, thereby inducing remineralization of the load-transmitting implant interface.

The above process can only be directed towards clinically successful healing as long as the osteolytic bone area does not become superinfected. Whether such superinfection occurs will depend not only on the bacterial load and the oral hygiene status but also on the length of the threaded pin, i.e. the distance between load transmission areas and the mucosal penetration.

Besides rare pain from mobile basal plates, no other direct pain signals or information stemming from the implants reach the brain. Information from the muscles and joints prevail. This is one of the main reasons why patients with implant-supported restorations adapt rather quickly to changes in the function path that was created by prosthodontic means.

10.10 Reflexes and Engrams

The movements of the mandible are controlled via the occlusal contacts in terms of height and via the masticatory surfaces in terms of direction. The applicable range of movements can be retrieved from the “main memory” of the neuromuscular system, which is continuously updated. Swallowing, by contrast, follows a reflex pattern that is exclusively inert in nature, thus being a “hardware-controlled” functionality, as it were. Mastication arises from an acquired and readily adaptable pattern of muscle collaboration, which can only take recourse to an undeletable backup if deviations from normal function occur. This backup is loaded into the main memory when the system is “rebooted” by eliminating functional obstacles. The loading of symmetrical engrams is facilitated by an ever-present inclination to re-run old engrams.

The muscles have the task of establishing the most pleasant contact relations between the maxilla and mandible – if possible by avoiding any bad contacts and painful sensations. In this way, any “bite” that is established by tooth or prosthetic contact is a locked bite, and any “bite taking” becomes a forced “bite delivery” in prosthetic contexts.

Avoidance of pain and atypical movement patterns can give rise to situations where interferences are not affected by incorrect loading themselves but inflict damage on seemingly unrelated teeth. This mechanism is not always obvious. The fact that a chain has broken at its weakest link does not tell us at which link the excessive force that caused the breakage occurred.

Reflexes are unchangeable, but engrams can be relegated from the main memory by newly acquired

movement patterns. Speech is driven by typical engrams. Whenever BOI-based fixed restorations are realized in situations characterized by advanced bone resorption, these patients may have a very hard time adapting their speech habits. The situation will improve by daily exercise. Patients will relapse into old engrams when they are sleepy, which is why phonetic performance tends to reach its lowest level in the afternoon or later in the evening and during the night.

10.11 Reconstructing the Chewing Function

While there are different ways the bilaterally balanced mastication pattern may collapse, all strategies to restore function are directed at establishing a correct masticatory plane and functionally oriented masticatory surfaces. As bite registration in the habitual position is exceedingly inaccurate, particularly when the muscle forces are reduced, restorations are fabricated and the intermaxillary relations defined based on the most dorsal relationship possible (Beyron 1969). Subsequently, the masticatory function paths have to be adjusted intraorally with abrasive instruments or by building up hard tissue. What we expect from the dental laboratory is a preliminary bridge, which will then be extensively adjusted in the patient's mouth. Whether another glazing step is performed once these adjustments have been performed has to be decided on a case-by-case basis. Any need for abrasive adjustments during the phase of gradual muscle relaxation cannot be dealt with by glazing because the porcelain build-up will tolerate another vacuum firing after having been in situ for an extended period of time. If that is the case, a new bridge is fabricated, or the existing framework re-veneered, if considered necessary from an aesthetic viewpoint. Temporary restorations on BOI-implants need to be very stiff. This requirement can be met by using thick layers of resin or a metal framework. Large-span bridges supported by a small number of abutments should always be cemented with strong cements or acrylic resin to compensate for any removing lever forces. Periods of temporary cementation (e.g. while the opposite jaw is awaiting reconstruction) should be kept short.

It is sometimes completely impossible to record a truly retral position of the TMJs, particularly if they have been greatly dislocated for many years. These situations may be due to permanently hypertonic chewing muscles (notably the lateral pterygoid muscle), or they may be due to jamming of the articular space by connective tissue structures that cannot be immediately repositioned. Substantial radiographic discrepancies in the relative positions of

the TMJs are indicative of this type of complication. Connective tissue structures in the articular space can be dealt with by adjusting the affected side to a slightly infraocclusal level. In our practice, we have routinely been able to re-establish optimal TMJ positioning in this way within a few months (sometimes accompanied by physiotherapy).

10.12 Implant Treatment as First-Line Therapy of Mastication

Some naive "experts" appointed by the courts, and even some representatives of academia, keep repeating the fairy-tale that the vertical and sagittal relations can first be restored by a removable restoration, followed by transferring the results to a fixed restoration down the road. This notion is absurd, if for no other reason that removable restorations cannot possibly restore a "normal" muscle function in the first place. The reader may want to consider the following metaphor: Imagine there is some gravel inside your right shoe. Now that you know it, everything is fine, so please stop limping right now. We are going to remove the gravel next week.

Also note that a denture cannot be reasonably retained even in situations of moderate bone resorption, which is plain from the very fact all the muscles involved (chewing muscles, mimic muscles and tongue) will specifically focus on the task of swallowing food without swallowing the denture. Complete dentures tend to be associated with chopping movements because any lateral movements are particularly detrimental to retention.

Restoring the masticatory function with the help of immediately loaded BOI-based restorations is not primarily advantageous because it offers a "quick fix" solution. Establishing a balanced chewing ability with fixed teeth is an important goal that should be achieved as soon as possible. In fact, the patients themselves tend to realize this importance. In many cases, the first step towards achieving this goal is to practise a correct masticatory pattern.

The next goals to be achieved in the longer term are to ensure that the implants become anchored in a lasting manner, that the bone structures reach maturity, and that the masticatory function, which had been gradually lost over the years, will be fully restored. In many cases, this reorganization of lost functions on the basis of skeletal bone structures will require additional steps. For instance, it may become necessary to insert complementary or additional prosthetic restorations or to replace any implants that are no longer able to fulfil their task of load transmission.

This comprehensive reorganization of the masticatory function can only be achieved in a number of successive steps – similar to successive layers of paint, where each single layer should be allowed to dry so that it can properly solidify before the next layer is applied. In the vast majority of cases, the first step must be to insert a fixed restoration as the departure point for all further steps of the prosthetic treatment. Sometimes it may be useful to improve or renew the existing denture before any implants are inserted, but these cases are very rare.

Dentures do not allow the building muscle power, and they are unable to create suitable functional conditions for the subsequent fixed restoration. All they can achieve is to simulate the vertical dimension, which is a theoretical consideration because the limitations imposed by lack of retention cannot be overcome in practice.

To avoid problems with patient compliance, it must be repeatedly pointed out to the patient that immediate loading of implants does not mean the immediate end of the treatment. The opposite is true: the active phase of functional treatment can only start after the placement of the fixed restorations.

10.13

Rationale of Creating a Balanced Function

With implant-restoration systems that are supported by numerous implants, it is difficult to determine the forces acting on individual implants. This task is quite easy, by contrast, with systems that are based on strategic implant positioning. Based on our knowledge of jaw flexion, masticatory function, the directions of muscle-induced forces acting on the cranial bone, and the equilibrium of forces acting on BOI implants, the relationships illustrated in Fig. 10.7 have to be taken in to consideration as a minimum requirement.

Patients should never be instructed to “avoid” specific sites where implants have become slightly mobile or are painful. Apart from the fact that this avoidance strategy is unlikely to be successful anyway, unilateral avoidance patterns will have the same undesirable consequences as habitual unilateral chewing patterns: the non-working side develops pull trajectories along the crest of the mandible, thereby reducing the tendency towards mineralization, which would actually destabilize the affected implants further. In the maxilla, the entire avoided bone region will be increasingly less mineralized, and the implants mobilized as well. In the upper jaw, this will more readily result in pain of a periosteal origin than in the mandible. BOI implants require adequate loading to be optimally integrated. The development of pull areas and mechanically

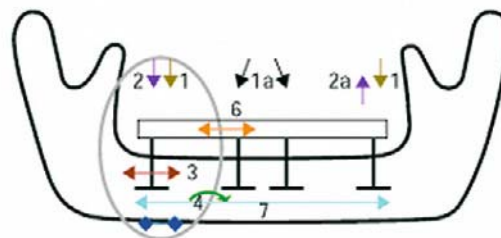


Fig. 10.8. Schematic view of the forces acting on BOI implants in a full lower bridge. Note that adding further implants at strategic positions may create hypomochlions, which add further forces to the strategic implants. 1, 1a Vertical and lateral chewing forces in the presence of bilaterally balanced loading. 2, 2a Vertical extrusion forces in the presence of contralateral loading. The implants in the anterior segments can influence the direction of the caudally oriented unilateral (non-balanced) loading of implant 37 to the point of creating an extruding force. 3 Dislocation of bone structures in the implant area by unilateral chewing on the left side. Tensile forces in the upper portion of the mandible. 4 Jaw flexion induced by normal mouth opening. The centre of flexion is variable. Its precise location is determined by the way in which the chewing force develops, by the sequence of any extractions, and by the type of the prosthetic restoration. 5 Compressive force countering the force described in item 3 during unilateral chewing. 6 Tensile forces transmitted from and to other jaw segments through the superstructure. 7 Dislocating forces of muscular origin with effects inside the jaw that shift the implant beds against each other as a result of function

weaker unloaded or inadequately loaded bone areas must be avoided at all costs. Any highly mobile implants should be detached from the superstructure (see Chapter 26) or exchanged. To summarize, it is absolutely contraindicated to instruct patients to avoid painful areas or to chew unilaterally. Any such attempts would further debilitate the already weak bone area and are liable to result in excessive loading of the working side. On the opposite side, which the patient wants to save from load, crestal tearing forces will reduce the mineralization of the bone matrix, leading to and increasing mobility of the implants. While it would be possible to avoid using and loading a broken leg, this one-sidedness is not possible in the jaws because “both sides” are installed on the same bone. Unilateral use will alter the distribution of 1- and 0-areas in an undesired manner.

For a better overview, let us briefly recapitulate the consecutive stages of normal mastication.

If the dentist prompts a patient to mark contacts on occlusal paper, the patient will perform movements that he or she does not normally perform while chewing, namely a lateral movement of the mandible from the centric position sideways. The exact opposite is the case during the normal masticatory act (Fig. 10.9):

- The mandible is elevated from laterally (“closure”).
- The teeth touch in an eccentric position and glide toward the centric position while contacting the food bolus (“cycle-in”); this is also called the “enter phase”. Very large forces are exerted on the restoration in this phase.
- The centric position is only maintained for a fraction of a second. Forces of different magnitude may occur during this phase. There is little contact between the teeth at this point.
- This is followed by the start of the “cycle-out” phase in which the teeth, while they are still chewing and crushing food, are already moving apart from each other again. In this phase, the chewing forces are low as the opening of the mouth is imminent.
- In the opening phase, there is no longer any contact between the teeth. The mandible moves in a vestibular direction to re-enter the closure phase.
- The greatest masticatory forces occur in the enter phase. This is why it is so important that bilateral support (balancing) is present in this phase; if not, the non-balanced opposing side will be subject to considerable extrusion forces, and powerful mastication is impeded by the tilting of the mandible (see Fig. 10.8, arrows 2, 2a)
- If equilibration of the forces at 2 and 2a is not possible by prosthodontic means, segmented bridges with many BOI implants and crestal implant types should usually be preferred to circular restorations.
- Since the centric position (around which much of the conceptual universe of prosthodontics traditionally revolves) is only achieved for a very short period of time, it hardly plays any role in actual reality – logically enough. While it does determine occlusal height, it hardly has any effect on correct or incorrect function.
- The masticatory function can only be evaluated if the occlusal paper is sufficiently thick for a realistic chewing situation to be simulated. The use of a thin foil (Shimstock and similar products) does not yield the same good result for diagnosis and therapy.

By contrast with the masticatory function, the swallowing function is controlled by reflexes and is not usually amenable to conscious influences. During swallowing, omnilateral tooth contacts should occur, and the contact information should not deviate or not deviate significantly from the information given during mastication. The tooth contacts during swallowing make a major contribution toward draining the periodontal tissues, i.e. Drumm’s control movements are not only there for control but also, to a not inconsiderable extent, for drainage.

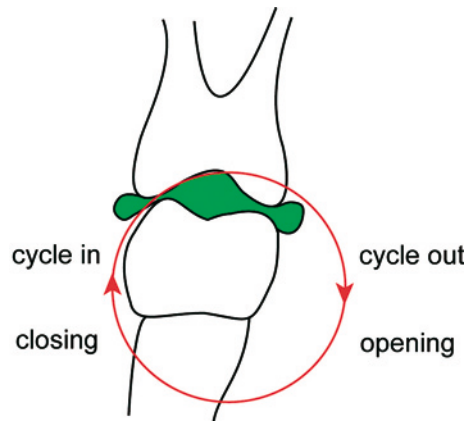


Fig. 10.9. The posterior teeth in the enter phase. The mandible has shifted laterally. Within the subsequent masticatory cycle, the vestibular cusp of the mandibular tooth will first glide along the cuspal inclines of the maxillary tooth with its vestibular facet. As it does so, the bite closes. The inclination of these two cuspal slopes must relate correctly to the inclination of the vestibular slope of the lingual cusp of the mandibular molar and the corresponding cusps of the mandibular molar on the contralateral side. None of these guiding planes should answer for guidance by itself (i.e. without any contralateral guidance) in the cycle-in phase

During swallowing, the tongue exerts formative stimuli on the palate and on the lateral aspects of the molars, while the pressure of the lips keeps the anterior teeth in line. When restoring an edentulous maxilla, a situation may occur in which the functional requirements no longer coincide with the patient’s aesthetic expectations. The reason will frequently be that the support of the soft tissues by the bone and the stimulation, position, location and inclination of the mimetic muscles no longer correspond to the situation when the patient still had all or most of his or her teeth. In cases such as these, a compromise must be found. This is the domain of epithetic therapy, since epitheses allow placing the teeth at a functionally favourable position even if the existing hard and soft tissues are not located favourably, successfully correcting any aesthetic deficiencies at a later point.

10.14 Mastication Therapy Allows Effective Bone Management

Bone structures will only be preserved if they are sufficiently loaded, activated, fed and drained. Restorative treatment based on BOI implants will yield successful outcomes even in extremely resorbed jaw structures. For this purpose, a symmetrical balanced and forceful chewing function has to be established and maintained. Therefore, the masticatory function

has to be periodically readjusted by subtractive or additive means.

Conventional restorations – whether fixed or removable – are always aimed at ensuring an acceptable masticatory function and at maximizing the life expectancy of functional teeth. Some, but not usually much, attention gets devoted to preserving the bone structures surrounding the teeth. The chances of influencing these bone structures by prosthetic means are bigger than we are used to think.

The situation becomes quickly obvious with BOI implants: The chewing forces are transmitted through the superstructure deep into the basal jawbone where the osseointegrated implant surface directly stimulates the bone and vibrates it. The masticatory surfaces have a modulating effect on jaw movements and therefore, by implication, on muscle function within the masticatory system. As the force impulses are created by muscles and transmitted into the bone via the restoration, the bone will undergo morphological changes in response to any dimensional or directional changes in masticatory direction. Due to its temporal dimension, this morphological reconstruction is referred to as the “fourth dimension of implantology” in this book.

BOI implants can induce vertical bone growth if required (Ihde 2003), provided no components of the implant-restoration complex (notably threaded pins, pontics or infections) interfere with the process.

Muscle function is controlled by the brain, but the brain can only make the oral muscles work on paths that are pre-determined by the dental restorations. Any other movements would fall into the categories of parafunction, facial expressions, etc.

Crestal implantologists have always postulated infraocclusion (where possible) and narrow masticatory surfaces as treatment objectives. We challenge this approach, because its results are incompatible with the requirement of laterally oriented chewing patterns, which are the only way to ensure that an adequate stimulus is present for

bone preservation and/or functionally induced the formation of new bone. Lateral movements create shear forces that allow the bones of the jaws to regain an adequate morphological shape.

Hielscher (1961) pointed out that the movement of the mandible is in no way guided by bone structures but is determined exclusively by muscle forces and muscle tone. It is incumbent on the BOI implantologist to realign these forces and to make the most of their ability to induce the formation of new bone.

10.15 Conclusion

If the edentulous spaces are narrow and long, firm roots are available for retaining the denture, as is the case in many younger patients, many creative prosthodontic designs can be taken into consideration. Almost all of them will allow the restoration to remain functional for a number of years. If the bone supply is reduced, however, it will be necessary to use a restorative technique that is compatible with the masticatory system as a whole. In our experience, the following objectives apply in the case of restorations supported BOI implants:

- Good masticatory balance accompanied by a degree of abrasion commensurate with age and by sufficiently extensive occlusal surfaces.
- Lateral masticatory patterns with equilateral AFMP angles should be generated.
- The occlusal plane must not be too deep distally.
- The curve of Spee must be adapted to the occlusion.
- The vertical dimension must be sufficient.
- The same number of chewing units, preferably of equal width, should be present in both quadrants of the jaw.
- All contact phases of the masticatory function must be present in the relief of the occlusal surfaces and carefully adjusted.

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Annex I: Recommended Cutter Sequence

No.	code ED / EDC	SD ₁	SD ₂	SD ₃	SA	Recommended Cutter-Sequence
461025	ED 7G5	0.6 - 0.8				462214
461028	ED 7G8	0.6 - 0.8				462214
461028	ED 9G8	0.6 - 0.8				462214 462259-W or 462221-W 462261-6 or 462261-4W or 462261-6W
461048	ED 9G8	0.6 - 0.8				462214
461058	ED 10G8	0.6 - 0.8				462214 462262-4 or 462262-6 or 462262-4W or 462262-6W or 462262-8W ^{*)}
461080	EDC 12 G6 - 8 (Ti15 Mo)	0.6 - 0.8				462264 462264-6W or 462214
No.	Code EDS	SD ₁	SD ₂	SD ₃	SA	Recommended Cutter-Sequence
461426	EDS 7G6	0.7 - 0.9				
461443	EDS 9G3	0.7 - 0.9				
461445	EDS 9G5	0.7 - 0.9				
461446	EDS 9G6	0.7 - 0.9				
461449	EDS 9G9	0.7 - 0.9				▶

No.	Code EDS	SD1	SD2	SD3	SA	Recommended Cutter-Sequence
						462261-6 or 462261-4W or
461451	EDS 9G11	0.7 - 0.9			462214	462259-W or 462221-W
461454	EDS 10G4	0.7 - 0.9				462262-4 or
461455	EDS 10G5	0.7 - 0.9				462262-6 or
461458	EDS 10G6	0.7 - 0.9				462262-4W or
461460	EDS 10G8	0.7 - 0.9				462262-6W or
461462	EDS 10G10	0.7 - 0.9				462262-8W
461466	EDS 12G6 - G9	0.7 - 0.9				462264-4 or 462264-6 or 462264-4W or 462264-6W
No.	Code EDAS	SD1	SD2	SD3	SA	Cutter-Code
461729	EDAS 7/14 G9	0.6 - 0.8			462214	462259-W or
461755	EDAS 9/12 G5	0.6 - 0.8			462214	462221-W
461757	EDAS 9/12 G7	0.6 - 0.8			462214	462261-6 or
461765	EDAS 9/15 G5	0.6 - 0.8			462214	462261-4W
461771	EDAS 10/14 G5 - G9	0.6 - 0.8			462214	462261-6W
					462214	462264-4 or 462264-6 or 462264-4W or 462264-6W ▼

No. EDD	Code	SD1	SD2	SD3	SA	Recommended Cutter-Sequence
461144	EDD 9G4	0,6	0,6		3	462214
461145	EDD 9G5	0,6	0,6		3	462261-6 or 462261-4W or 462261-6W
461225	EDD 9/7 G5	0,6	0,6		3	462237 or 462237-W
461165	EDD 10G5	0,6	0,6		3	462262-4W or 462262-6W
No.	Code	SD1	SD2	SD3	SA	Recommended Cutter-Sequence
461514	EDDS 9/7 G7	0,6 - 0,8	0,6		3	462261-6 or 462261-6W or 462261-4W or
461520	EDDS 10G4	0,6 - 0,8	0,6		3	462261-6W or 462261-4W or 462262-6W
461521	EDDS 10G5	0,6 - 0,8	0,6		3	
461524	EDDS 10/7 G4- G8	0,6 - 0,8	0,6		3	
461526	EDDS 10/7 G8	0,6 - 0,8	0,6		3	462237 or 462237-W
	EDDS 12/8 G5, G6, G7, G8	0,6 - 0,8	0,6		3	462264-4 or ▼

No.	Code EDDS	SD1	SD2	SD3	SA	Recommended Cutter-Sequence
461530						462264-6W
No.	Code EDDD	SD1	SD2	SD3	SA	Recommended Cutter-Sequence
461210	EDDD 9/7/7 G3- G7	0,6	0,6	0,6	3	462214 462255 or 462261-6W
461213	EDDD 10/7/7 G3- G7	0,6	0,6	0,6	3	462214 462255-W 462262-6W
No.	Code EDDS	SD1	SD2	SD3	SA	Recommended Cutter-Sequence
461925	EBBBS 7 G3- G7 EDDS 7 G3- G7	0,6	0,6	0,6	3	462255 or 462255-W
No.	Code EDXAAS	SD1	SD2	SD3	SA	Recommended Cutter-Sequence
461805	EDXAAS 10/20 G5	0.7 - 0.9				
461806	EDXAAS 10/20 G6	0.7 - 0.9				46222-4W or
461807	EDXAAS 10/20 G7	0.7 - 0.9				462259-W or 462262-6W
461808	EDXAAS 10/20 G8	0.7 - 0.9				462221-W
461809	EDXAAS 10/20 G9	0.7 - 0.9				▼

No.	Code EDXADS	SD1	SD2	SD3	SA	Recommended Cutter-Sequence
9/14 G5 0.7 - 0.9	EDXADS					462261-6W or 462261-6 or 461835
461837	EDXADS 9/14 G7	0.7 - 0.9				
461824	EDXADS 12/17 G5 -G7	0.7 - 0.9				462264-4 or 462264-6 or 462264-4W or 462264-6W
No.	Code EXDDS	SD1	SD2	SD3	SA	Recommended Cutter-Sequence
461308	EXDDS 12/9 G5 ²⁹	0.7 - 0.9	0,6		5	462264-6 or 462264-6W
461310	EXDDS 12/10 G6	0.7 - 0.9	0,6		5	462262-6W or 462262
461312	EXDDS 14/10 G6	0.7 - 0.9	0,6		5	462245-6W or 462245
461322	EXDDS 15/9 G7	0.7 - 0.9	0,6		5	462214
461324	EXDDS 18/15- 10/12 G4	0.7 - 0.9	0,6		5	462264-6W ▶

No.	Code EB	SD ₁	SD ₂	SD ₃	SA	Recommended Cutter-Sequence
461663	EB 9G3	0.6 - 0.8				462214 462259-W or 462221-W 462261-6 or 462261-8W
461672	EB 12G6	0.6 - 0.8				462261-4W or 462261-6W 462264-6W or 462264-6
SD ₃ SD ₂ SD ₁	SD 1-3 = Thickness of base plate; ring to center SA = inter-disk distance					

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